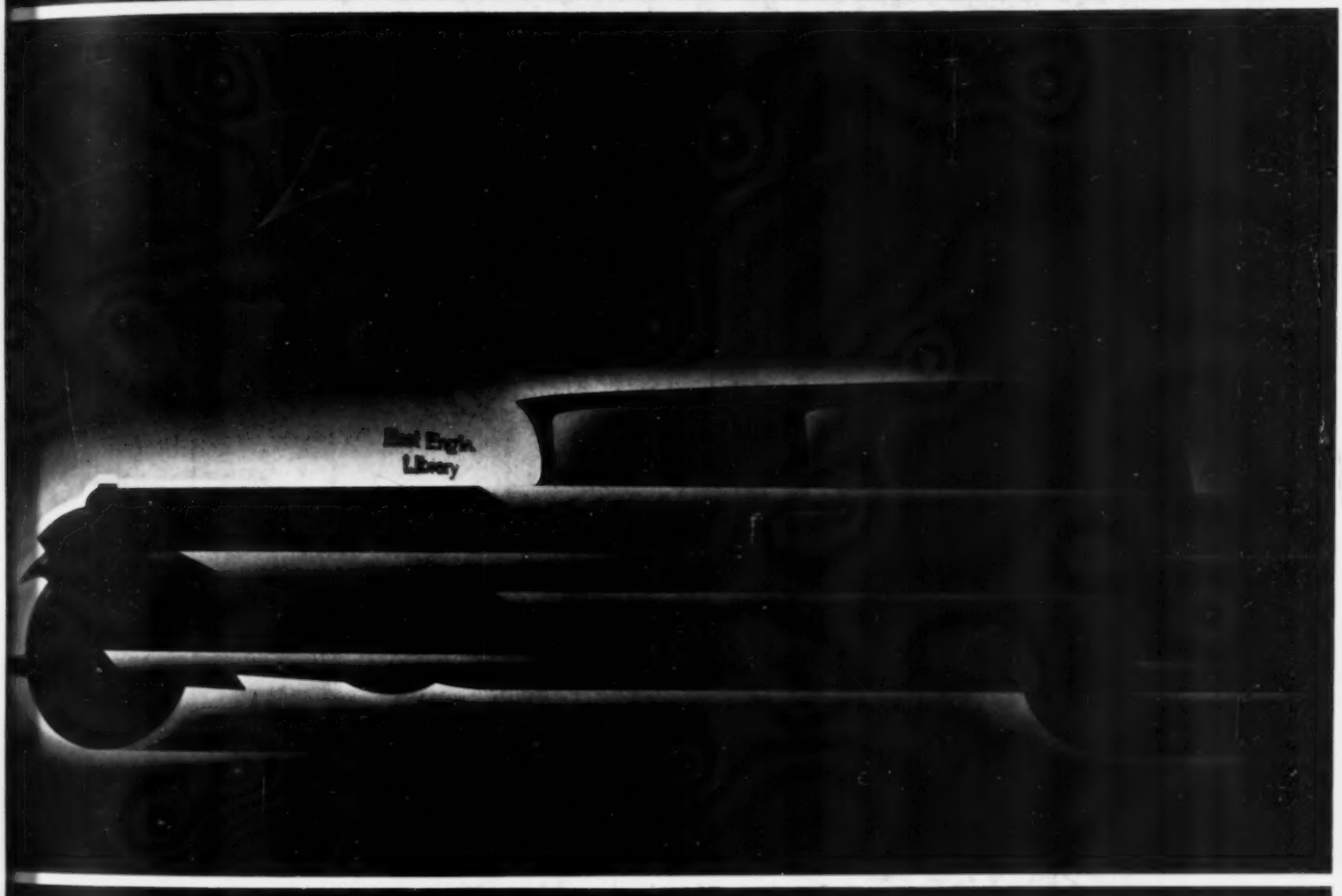
METAL PROGRESS



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MARCH 1932

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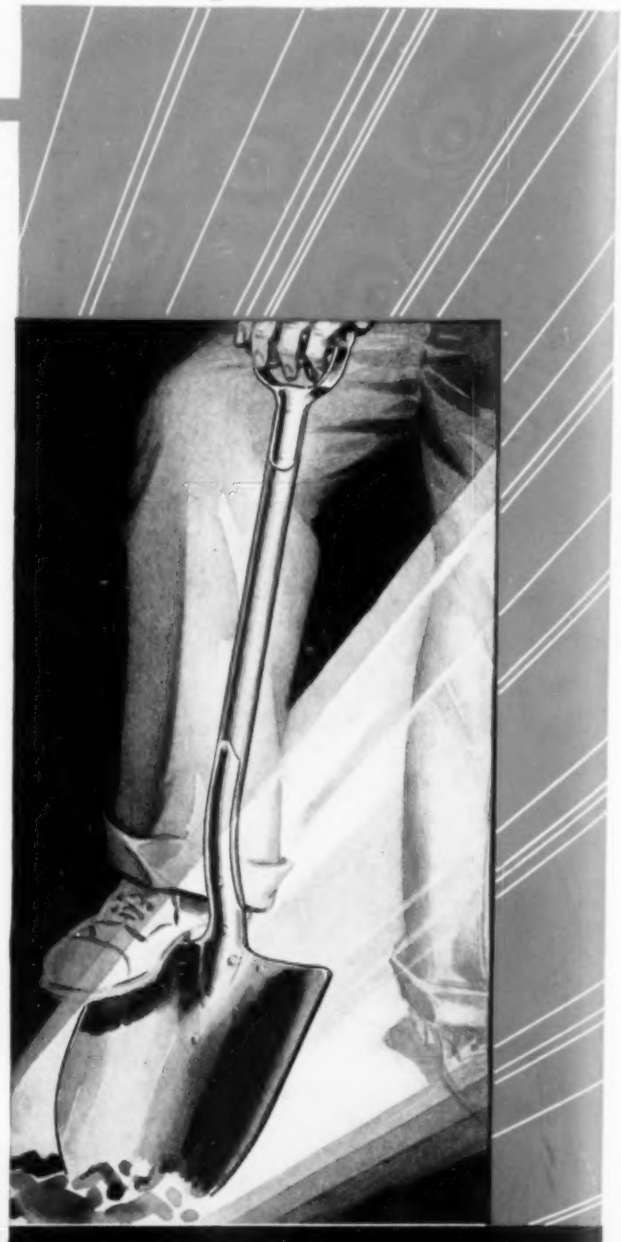

CENTRAL ALLOY DIVISION
REPUBLIC STEEL
CORPORATION
Massillon, Ohio

AGATHON ALLOY STEELS

Metal Progress

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Ernest E. Thum, Editor

MARCH, 1932 VOL. 21, No. 3

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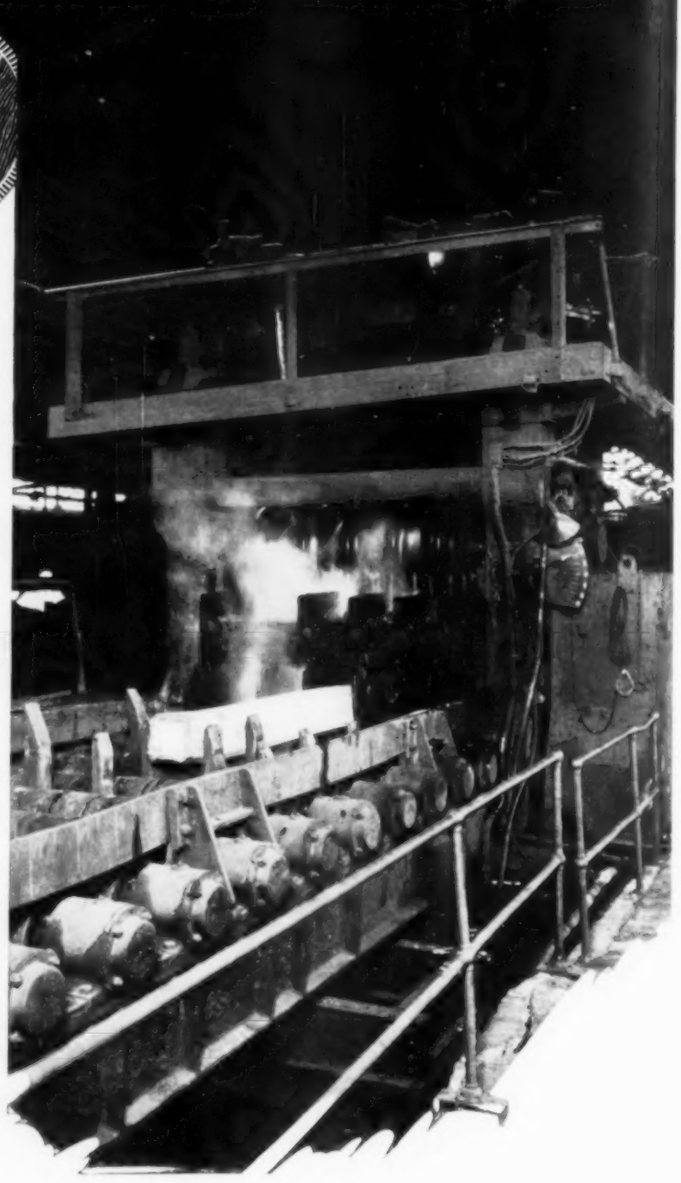

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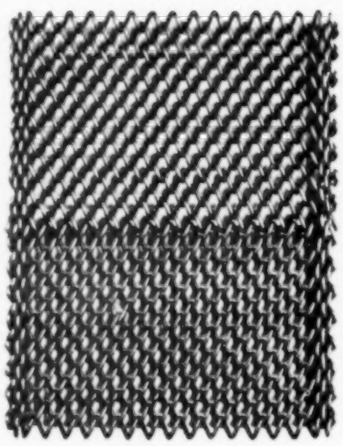

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Rough Going in the Lumber Woods

Furnaces Placed in Production Lines

By GORDON T. WILLIAMS
Metallurgist
Cleveland Tractor Co.

. . . THE FUNDAMENTAL REquirement of modern manufacturing on a large scale is the production of interchangeable parts of maximum quality and at minimum cost, since mass production and low costs to the consumer predicate the assembly of products from interchangeable parts, manufactured from controlled materials, with standard dimensions, tolerances, and properties. Such an achievement demands specialized tools and equipment, wage incentives to spur the workmen, and a minimum of lost time and handling through the closest possible linkage between successive operations. The more closely associated the group which produces a given part, both in the plant layout and as to its objective, the more economy will be attained.

Heat treating, as we all know, is frequently an essential operation in the line between raw material and finished part. In the majority of plants, both large and small, the necessary furnaces have their own building or separate niche where these "specialized" operations can be performed without disturbing the other machines often regarded as of a higher type and more precise. In contrast with this plan of management, which may be called centralized heat treating, this article will describe successful decentralized, or production line, heat treating. It will refer to heat treating operations conducted in specialized equipment placed in proper physical relation to preceding and subsequent fabricating operations, and under the same supervision, leadership, and wage basis as the other machining and assembling operations.

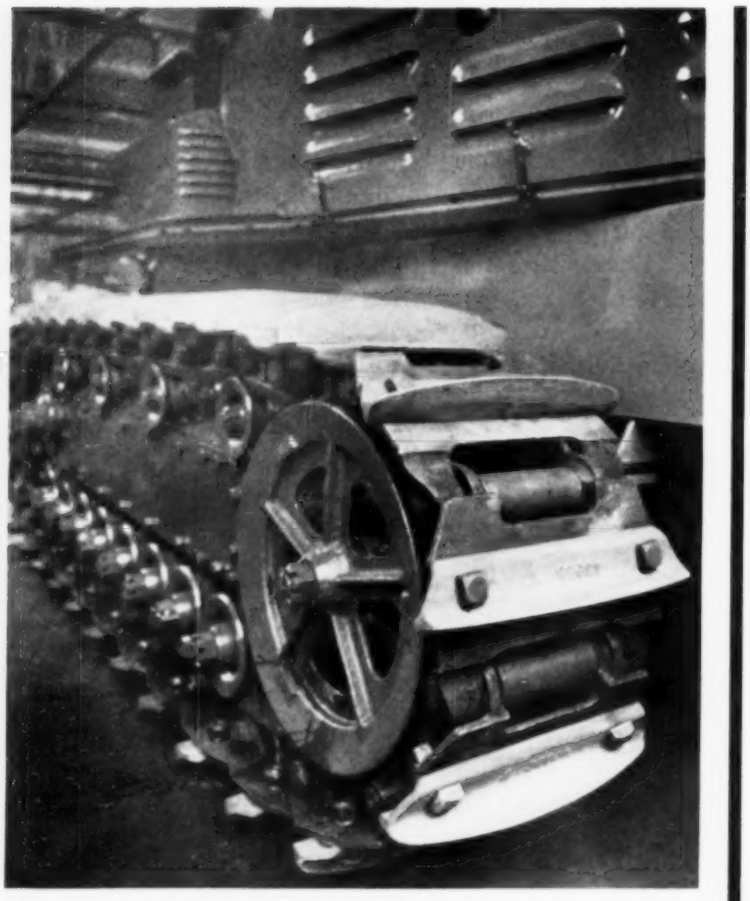
Furnaces for forging and similar hot working operations are always placed close to the presses and hammers, but, as noted above, production heat treating in manufacturing plants has usually been performed in a department segregated from other operations. That part of the plant referred to contemptuously by many employees as "the hardening room" or the "heat treat" has long been a spot notable for fumes and dirt, where costs (if known) were high and where "secret" processes were performed in mysterious ways.

The centralized heat treating department, as usually installed and managed, demands transportation of all parts to and from the furnaces, and a labor system at variance with best practice in the other machining and assembling operations; it means a subdivision of natural groups established elsewhere for the production of finished pieces, both through the physical separation of certain stages in the process and by the introduction of labor not under the control of group leaders.

Attempts to tie in the heat treat with other fabricating operations by conveyors have usually been only moderately successful, because the thermal operations have been performed by a group of men not correlated with those in the rest of the shop as to leadership, incentive, or objective. Of course, such conveyor systems, both inter-group and intra-group, decrease handling costs and lost time by linking together all production units without manual transportation. At best, however, conveyors are primarily a means of overcoming physical limitations imposed by plant layout and product design.

Heat Treating Machines

Once upon a time there was considerable justification for putting all furnace work into a separate building, for the crude equipment



Crawler Tractor Rides on Endless Chain. Short links ride easily around end wheel and sprocket, and are connected together with pins, bushings, and rollers

then available was a prolific source of noise, dirt, smoke, smell, and heat. Modern furnace design, on the other hand, is far from the box or batch-type units of ten years ago, and makes available automatic or semi-automatic equipment, full automatic control, and a degree of accuracy which is in harmony with that which is performed in the machining operations.

By proper selection of furnace equipment, with due consideration for cleanliness, simplicity, economy, and accuracy of results, heat treating units may today be placed directly in line with machine tools and operations, with a real improvement in the economy of manufacture and the quality of product. Furnaces may be regarded as "heat treating machines"; the human factor is submerged, and it is therefore possible to apply wage incentives or group bonuses figured on a basis of the number of finished parts produced.

Such heat treating machines will usually be special furnaces, of continuous operation rather than of the batch type. Unfortunately, when selected for optimum performance on a single operation on duplicate parts, a furnace will frequently be useful only for that particular operation or for parts of similar design. When product design or processing is changed so as to necessitate different heat treating programs, extensive alterations may be required before the old equipment is again usable.

For example, if or when box carburizing is superseded by some other method of securing hard surfaces, the recuperative and counterflow furnaces, which cost hundreds of thousands of dollars in the aggregate, will be obsolete and useless unless they can be rebuilt. The same, of course, is true of other production machinery. Its advantages in increased quality and lowered costs are usually more than sufficient to insure against the possibility of early obsolescense.

When correct heat treating units are adjacent to machining operations, thermal treatments may be performed by the same class of labor as the other stages in processing, and a group bonus plan of wage incentive can be applied, wherein payment is made on a basis of completed parts or assemblies accepted by the inspection department. This permits a unified supervision and leadership, and all men in one group have one objective — the economical production of the largest possible number of interchangeable parts.

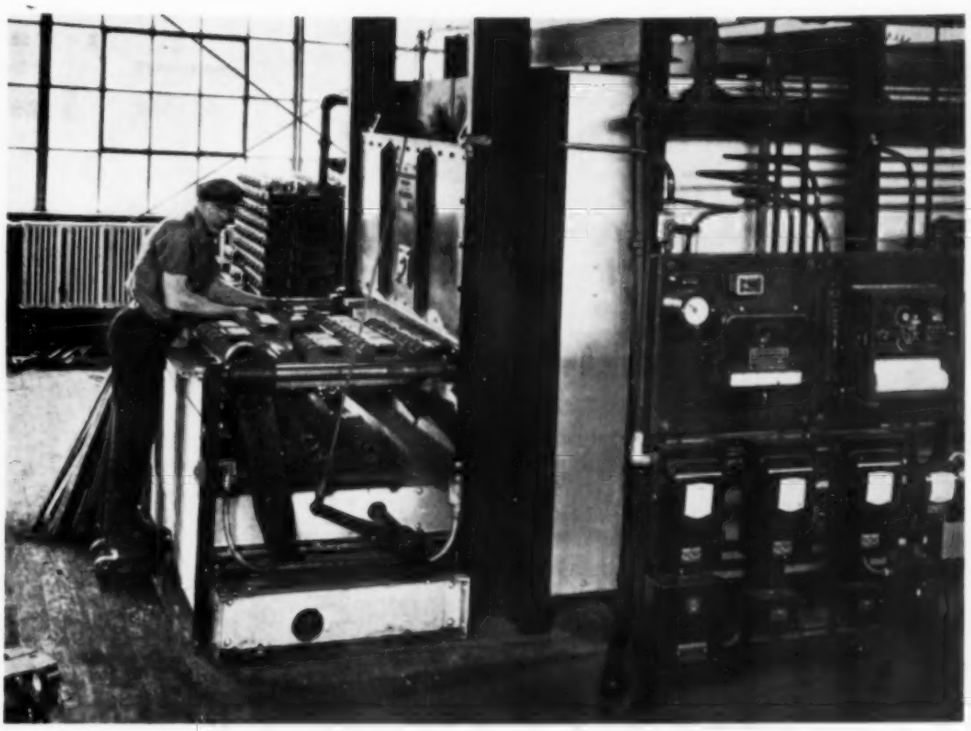
Decentralized Heat Treating

The Cleveland Tractor Co., after full consideration of the above-mentioned arguments, has abandoned a centralized heat treating department in favor of the decentralized units, thus achieving integral and complete group system in many of its departments. CLETRAC crawler tractors are the sole products of this company, the line including five standard machines, varying from 15 to 80 hp. drawbar capacity.

Liberal use of heat treated alloy steels and forgings is necessary to meet the severe service to which these machines are put; the Cletrac 35, a 40-hp. tractor, has 260 heat treated forgings, exclusive of those in the motor, and over 200 other heat treated parts, such as those cut from bar stock, castings and springs, not counting cap

screws, studs, or other minor devices. Many of these are located in the track and its supports, and the departments for fabricating these sub-assemblies may well be taken as illustrations of the general argument given above.

In the crawler tractor, an endless articulated track passes over upper track support rollers, around a front idler, under lower tractor supporting rollers, and is driven by a rear sprocket wheel which derives its power from the engine-driven transmission. The enormous amount of traction obtained by the flat track in contact with the ground permits the application of high power, but, at the same time, the relative freedom from slip demands gears, shafts, pins, and links of high shock-resisting qualities and capable of withstanding severe overloads. It should further be noted that tractors often operate steadily at full load, hour after hour.



Pusher End and Automatic Control of Gas-Fired Furnace for Track Shoes. Shoes are quenched in shallow water so only the lower edges are hardened

A word concerning the general plant layout may not be amiss. The Cleveland Tractor Co. plant occupies a series of one-story buildings about 325,000 sq.ft. in area. In general, operations may be described as "progressive" rather than straight line. Each department is equipped with its own hoists and conveyors — overhead or roller — to transport the parts from machine to machine.

The assembly building is grouped as a ladder — that is, the receiving tracks and conveyors parallel one side of a long building; storage bins and racks are just inside; raw material and parts work across the building to sub-assemblies on the far side, and to a main assembly aisle alongside the wall opposite the receiving tracks.

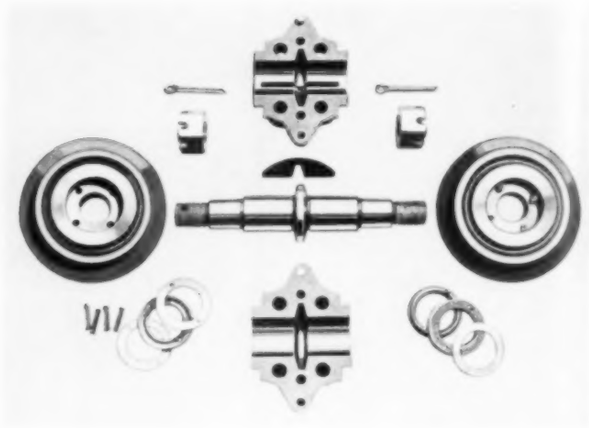
One production group in this plant which exemplifies decentralized heat treating is that making the components of the crawler track. Components and assembly can be judged from the illustrations. A typical track is in effect a chain belt, the links of which are track shoes — one-piece drop forgings of S.A.E. 1045 steel. The forgings, purchased outside, are delivered directly to the pusher end of the heat treating furnace, a gas-fired unit automatically controlled, with capacity of 2000 lb. per hr. Heated shoes slide out on a curved apron and discharge on a flat conveyor in the quenching tank, which is only $\frac{3}{4}$ in. under the water level. Thus the edge flanges only are quenched, hardening the "rails" which ride on the support rollers. Circulation is provided by a pump, return water being expelled through nozzles below the first three feet of the conveyor.

All Track Parts Hardened

Further conveyor motion carries the shoe up out of the water, and the hardened rail is drawn by the residual heat working back from the balance of the shoe. At the end of the quenching conveyor are drilling and reaming machines preparing the shoe for assembly. Rails of shoes are held to Brinell 350 to 450, while

the balance of the shoe is from 200 to 250. The softer tread plate on the shoe gets little wear, because "grouters" appropriate to the terrain are bolted on them.

Pins, bushings, and rollers for assembling shoes into a complete track are started from bar or tubing stock stored in racks, one side of which faces the cut-off machines, the other the railroad siding. Pins are of S.A.E. X-1315, bushings of S.A.E. 1020 seamless tubing, and rollers of S.A.E. 3120 seamless tubing. From cut-off, these parts move successively through all machining operations, including broaching, turning, chamfering, and drilling, to the rotary gas carburizers, located adjacent to the last machining operation. At present, four rotary gas carburizers, two gas heated, and two electric, are used. An average of 10,000 to 12,000 lb. is carburized in 24 hr. in these units, with direct labor of about four man-hours, work being performed by machine operators. (It might be remarked here that box carburizing on the same production in the old department required about 18 man-hours, or 4½ times as much labor.) Specifications call for a case from 0.030 in. to 0.090 in., depending on tractor size. Work is discharged after carburizing into baskets in a subfloor water quench.



Track Wheels Include Cast Iron Bearing, Hardened and Ground Shaft, and Wheels With Hardened Rims

Baskets are then carried by monorail conveyor to an adjacent hardening furnace. This unit has a V-grooved hearth, is heated by electricity, has an automatic timed pusher, and capacity of 800 lb. per hr. Work is discharged through a chute into a 6% sodium hydroxide solution, agitated by a propeller directly below the furnace discharge chute. Carburized and hardened pieces are taken from the quench by a conveyor through a boiling water rinse tank, which lands them at the point of assembly with the shoe. Hardness inspection is by Rockwell tester, the minimum being C-63.

In our design of track, the roller for contacting with sprocket teeth floats freely on a bushing which in turn is pressed into reamed holes in the narrow end of the shoe; step fit gives equal pressure on both holes. This operation is the last performed in this group, the assembled shoe being placed on the conveyor and carried to the tractor assembly line, where another pair of hydraulic presses assembles the shoes into a track by pressing in the pins. Two complete track assemblies are required, one on either side of the finished tractor, and weigh from 1150 lb. for Model 15 to 3600 lb. for Model 80.

All operations within the above group are conducted under one foreman; all workers are

Hardening Furnaces for Steel Shafts Set at Proper Place Amid Other Machinery. Cold shaft introduced through charge-hole, and hung on spider. One rotation of spider brings it back under charge-hole and it can be withdrawn at full heat for quenching

on the same bonus basis and share equally in benefits, payment being made on a basis of finished shoe assemblies.

Another excellent example of progressive production with unified control is the group producing the track wheel assemblies, which are the rollers supporting the tractor. As shown in the figure, the components are a two-part cast iron bearing, a heat treated shaft, two idler wheels, two oil sealing rings, oil feed wick, and minor parts.

Three parallel lines of machines simultaneously produce the shafts, the bearings, and the wheels. Shafts, which are of S.A.E. 1035, finally reach the heat treating units, which consist of electrically heated furnaces. Each furnace has a vertical shaft on its axis; the shaft carries spiders and hangers. The shaft is introduced through a round hole in the top of the casing, hung on the spider, and one revolution brings it to heat for hardening. It is withdrawn from the same charge-hole and replaced by another. Sodium hydroxide solution quench, water rinse, and Homo draw complete the heat treating layout.

Each "spider furnace" has a production of 150 lb. per hr. From 14 to 26 shafts, weighing from 5¼ lb. to 23 lb. each, are required for each tractor. Shafts are drawn at 800° F. to Brinell 321 to 375. The use of the NaOH quench has eliminated 99% of the erratic results formerly encountered with S.A.E. 1035.

After heat treating the shafts are ground, and are then at the proper location for subassembly with the cast iron bearing. This unit then picks up the wheels, which have been machined in their own line, and the lower track wheel assembly is thereupon completed, ready for the major assembly with the side frame, finally reaching the tractor on the adjacent main assembly line.

Track wheels are drop forgings of S.A.E. 1045, heat treated by the vendor to give a rim or wearing surface hardened to Brinell 400 minimum, the hub remaining machinable at a Brinell hardness of 250 maximum.

This lower track wheel assembly is, like the shoe, produced entirely under one supervisor by one group, all men operating on an equal bonus basis. Heat treating operations are handled exactly like a machining stage.

Further extensions of the above system of labor and product control in the Cletrac plant are planned for the future. Gears and shafts, for example, will be carburized, hardened, and drawn within the machining department by labor under supervision of the department foreman. (Gear hardening furnace is electrically heated, with a flat link conveyor hearth, having a capacity of 800 lb. per hr.) Ultimately, only miscellaneous parts, too small in quantity to permit specialized equipment, will be handled in a centralized group of general purpose furnaces.

Furnace units described above have proven very satisfactory, and may well be considered heat treating machines, whose installation in the proper physical relationship with preceding and succeeding operations has given better quality, better economy, and greater production. Lost time, due to poor coordination between machining and heat treating, with consequent "buck-passing" and excessive labor costs, has been eliminated.

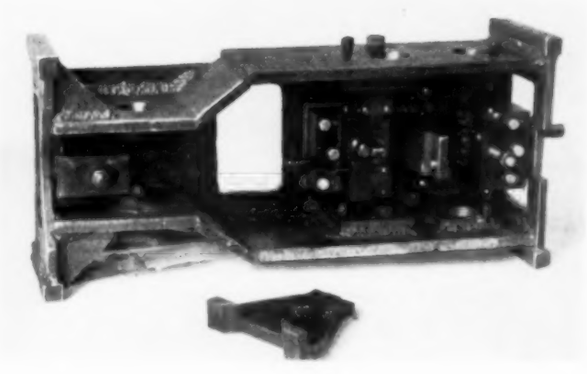
Bulldozing Broken Rock on Side-Hill Road Construction Demands Utmost Power and Stamina

Jigs & Fixtures Made of Welded Steel

By J. R. WEAVER
Westinghouse Electric & Mfg. Co.
East Pittsburgh, Pa.

TOOLS FOR TOOL MAKING REFER to fixtures that are used in conjunction with machine tools to hold and locate the work so interchangeable parts can be produced within the accuracy specified by the designer. I am wondering whether this class of tools is really given sufficient attention to obtain all possible advantages in the manufacture of standard apparatus. I do not doubt but that those firms which manufacture tools exclusively give this matter considerable thought. However, my article is written to reach mainly men in other industrial concerns, who supervise their own toolrooms and build fixtures for use in their regular machining operations.

Quite a number of years ago the tool department was looked upon by some managers as something that they had to endure; they were not fully convinced that it was absolutely necessary. To such a man it seemed that the tool department always spent considerable money, and reduced the dividends to that extent. I know of some who actually tried to discontinue tool departments.



I believe that the present-day manager fully realizes its importance. Recently, I talked to an engineer from a large machine tool manufacturing company, and he told me of a new machine which he had just designed. He obtained estimates from his shop of the cost of building the machine and found that approximately $100,000 would be spent for jigs and fixtures before a single one would be made. Since this machine was a rather large one in that particular line, and his company could expect to sell relatively few of

them, the production over a 5-year period would require that this expenditure be spread over about 100 machines. On this basis, the preparatory cost would be about $1000 for each machine.

Since this seemed quite high, he further investigated what the cost would be if he did not tool it up, and found the figure to be $2000 more to build this machine without tools!

This one instance would indicate what I firmly believe to be true — that low selling costs are to a very great extent due to proper tooling. Therefore, more attention should be given by the manager to the tool department; he should make sure that proper facilities are provided, and the fixtures properly designed and manufactured by the best men and methods obtainable. The results will undoubtedly be reflected in the quality and economy of the general output.

Shorter Time for Preparation

Under present conditions, time is of the utmost importance. No one buys today until he absolutely must have the apparatus he wants. Therefore, it is necessary for the vendor to produce it in a very short time. This necessity for speed is reflected back into the various preparatory operations, and the manufacturing equipment department at the East Pittsburgh works of Westinghouse Electric & Mfg. Co. (of which the writer is superintendent) is frequently called upon to produce tools on extremely short deliveries.

As a recent example, one of our shop supervisors came to me and said that he had to have certain tools and fixtures within 24 hr. These tools were rather large and consisted of milling, drilling, and checking fixtures for a fairly large piece of apparatus. Fortunately for him, we did not have to depend on cast iron or steel for our end of the job, for it is not always possible to pick up castings suitable for this type of work, and if a casting can be found quickly, it usually requires an excessive amount of machining and labor in order to produce the desired results — all of which, of course, takes considerable time.

However, we have adopted welded construction for all jigs and fixtures, and because of this change in the method of manufacturing, we were able to produce these tools within the required time. It can readily be seen that it was an easy matter to find the necessary material, since the desired shapes were cut from rolled steel plate and bars on hand with an oxy-acetylene cutting blowpipe and fabricated in less time than it would take to make a pattern. Machining time was small, because the parts were joined for a minimum amount of machining; if a casting had been made in a rush it would undoubtedly have required more machine work because time would not allow us to provide proper coring to keep the finishing labor at a minimum.

We have standardized on the welded jig and fixture throughout our East Pittsburgh works. There are no tools of this nature now made from castings. We have very thoroughly investigated the problem for three years, and after a series of tests for accuracy, stability, strength, and maintenance, have found that the fabricated jig is better. In all this time we have found no disadvantages to reside in the new method, but have discovered quite a number of advantages — especially from the standpoint of maintenance.

This matter of maintenance is important. It is oftentimes necessary to change the details of a tool, either while it is in the process of manufacture, or after it is completed. Welded steel construction

One of Several Oxy-Acetylene Cutting Machines Available for Preparing Diaphragms, Webs, and Various Other Sub-Assembly Units for a Welded Jig

adapts itself much more readily to these changes than a cast jig. If some minor change is necessary, it can easily be done by removing the obstructing part by an acetylene blowpipe, or a new part can be welded on where it is required. Such changes are impossible in cast jigs except by an excessive amount of work (frequently by obtaining a new casting).

We find that maintenance costs are now only about 15% what they had been with cast fixtures. I believe this very gratifying condition is due to the greater strength of welded steel. Further, the new fixtures are materially lighter than the corresponding ones of five years ago, thus reducing the liability of damage during handling. Lastly, it is very easy to place or replace hardened steel inserts or pads where wear is greatest.

Start With the Designer

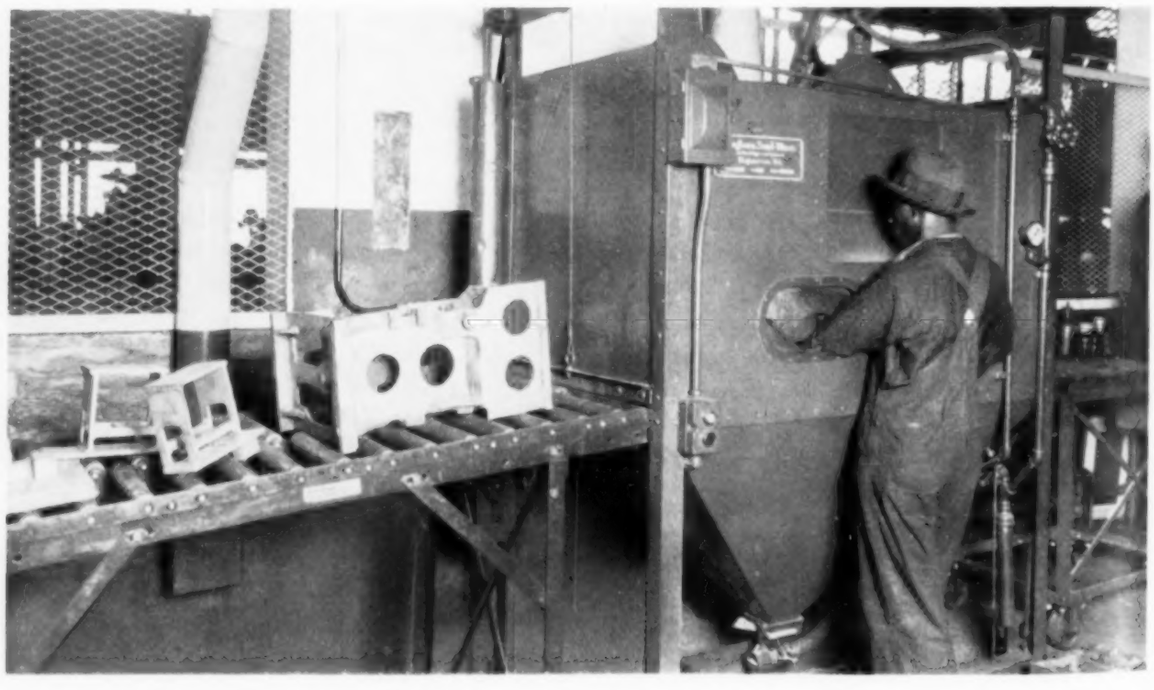
To obtain the full advantage of the above improvements in fixtures, it is first necessary to train the tool designer. Unquestionably, this type of fabrication is entirely different from the cast type, and, if the tool engineer designs a fabricated tool as he would a cast tool, the full advantage of the former would not be realized.

For this reason our tool designers were given an intensive course of instruction to make them sufficiently conversant with the use of welding terms and the principles of welding design so they might intelligently transmit their ideas to the shop. To assist the program, several instruction sheets were created for the designers' use, which not only gave the shop workmen information, but also standardized certain phases of the manufacture.

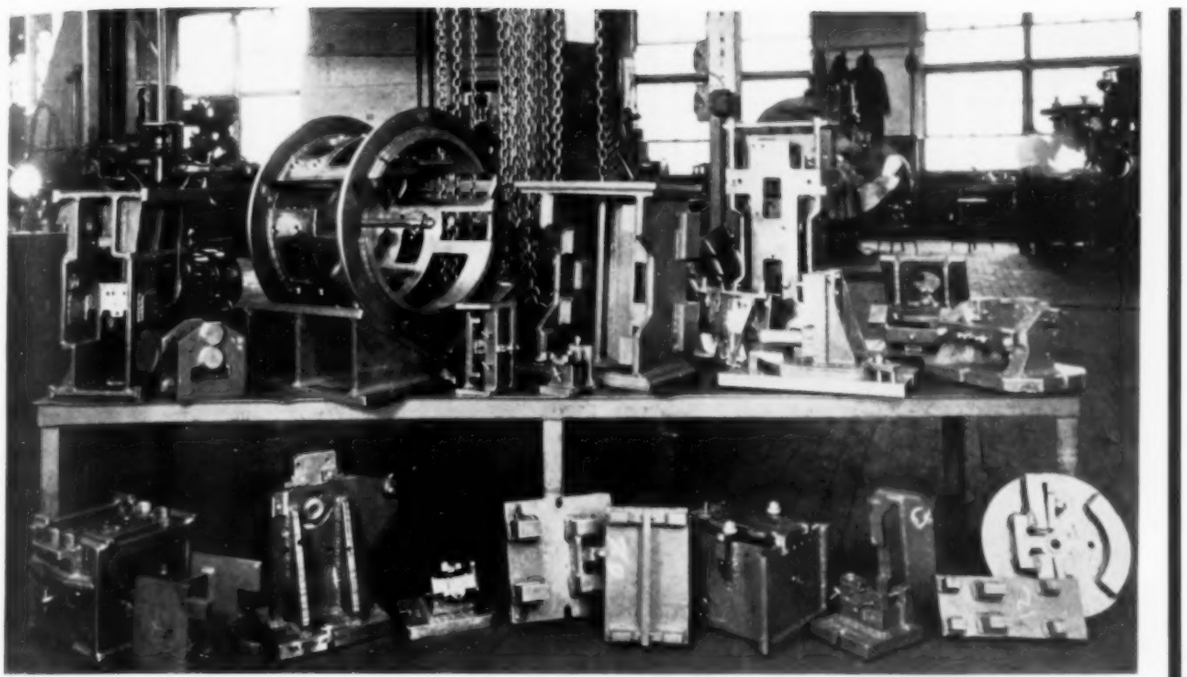
One of the standard sheets is shown on page 36. It gives the various types of welds and the correct size of bead. Any reference made on any sketch to data on this sheet is readily understood by men on the welding floor where the jigs are fabricated.

In order to avoid delays from shortage of stock material, another sheet was approved for showing the standard sizes of bar and plate most generally used and kept in stock (together with number of purchasing department specification for re-order). When the bar stock is not suitable, the part is cut to size from a plate by means of a blowpipe.

Boiler plate of widths and lengths commonly used in the tank shop is kept on hand in



Welded Assemblies Are Given a Stress Relieving Anneal, Then the Scale Is Removed by Sand Blasting, and the Clean Jig Spray Painted Before Machine Work Is Started



There Is no Limit as to Size or Complexity of the Jigs and Fixtures Made of Welded Steel at the East Pittsburgh Works of Westinghouse Electric & Mfg. Company

thicknesses from $^3/_8$ to 1 in. by eighths. A considerable variety of hot-rolled steel plates, rounds, and bars is also carried as follows: Plates from $1^1/_4$ to $3^1/_4$ in. thick by quarters; rounds from $^3/_4$ to $3^1/_2$ in. by quarters; bars range from $^3/_8$ in. thick by $^3/_4$ in. wide to 1 in. thick by 4 in. wide, the thicknesses varying by eighths and the widths as follows: $^3/_4$, 1, $1^1/_2$, 2, $2^1/_2$, 3, and 4 in. in each thickness. A selection of carbon tool steel bars is also carried, ranging from $^1/_2$x1 in. to 1x2 in. cross-section.

The machine designer makes no reference to welding on his drawing. The tool designer makes a separate sketch, which, with the above-mentioned standards, gives the shop complete information for the correct jigs, including welding, machining, and complete bill of material.

Hot rolled steel is used in the body of the jigs. Where hard pieces are required, they are made from carbon tool steel, hardened and attached to the jigs by means of screws or bolts. Hardened bushings are pressed into proper drilled holes.

In order that chips may not imbed themselves into the jig feet, it has been found advisable to make this portion of tool steel. They are heat treated to a scleroscope hardness of 45 to 50 before being welded to the jig.

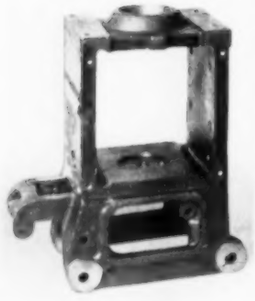
Several different types of machines are used in the shop for cutting the appropriate parts from plate stock. Each one consists essentially of an oxy-acetylene blowpipe mounted on a suitable frame, so it can be easily guided around the outline of the part to be cut.

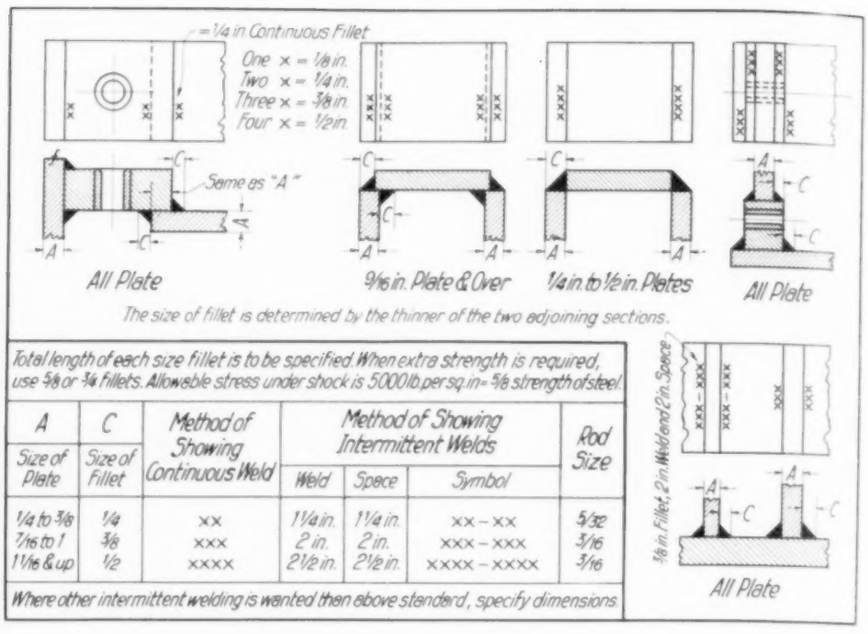
The jig parts are then assembled by a mechanic, properly squared up, clamped in place, and tack welded sufficiently to hold them together. The work is then passed on to the welder who completes the job.

Constant Accuracy Maintained

In order to remove any strains present in the structure, the jigs are normalized by heating to a temperature of 1000 F., after which they are allowed to cool in the air. This produces a scaled surface, so the appearance of the product is improved by sand blasting. The jigs are then sprayed with an oil-resisting paint so as to prevent chips from sticking to them when in use.

Final machining operations differ from corresponding work on cast jigs, as only about one-fourth the amount of material is now allowed for finish as formerly.




1/4 in. Continuous Fillet
One × = 1/8 in.
Two × = 1/4 in.
Three × = 3/8 in.
Four × = 1/2 in.
Same as "A"
All Plate
9/16 in. Plate & Over
1/4 in. to 1/2 in. Plates
All Plate
The size of fillet is determined by the thinner of the two adjoining sections.
Total length of each size fillet is to be specified. When extra strength is required, use 5/8 or 3/4 fillets. Allowable stress under shock is 5000 lb. per sq. in. = 5/8 strength of steel.
Where other intermittent welding is wanted than above standard, specify dimensions.
9/16 in. Fillet, 2 in. Weld and 2 in. Space
All Plate

A	C	Method of Showing Continuous Weld	Method of Showing Intermittent Welds			Rod Size
Size of Plate	Size of Fillet		Weld	Space	Symbol	
1/4 to 3/8	1/4	XX	1 1/4 in.	1 1/4 in.	XX – XX	5/32
7/16 to 1	3/8	XXX	2 in.	2 in.	XXX – XXX	3/16
1 1/16 & up	1/2	XXXX	2 1/2 in.	2 1/2 in.	XXXX – XXXX	3/16

Size of Weld Is Proportional to Thickness of Plate Being Joined, and Designer Conveys Information by Conventional Symbols

After several years of use, we are convinced that such work in the tool department helps us to give proper service to our customers and to keep our costs to a minimum. Of course, other things in our toolrooms have helped, such as wage incentive, improved production methods, and cost analysis. I think a proper tool has a decided influence on the standard of the apparatus being manufactured for sale. It is the means of making either a good or a bad product, or, if good, it is a means of making it either expensively or at a low cost.

It is desirable for the apparatus designer to be familiar with the facilities and the personnel in the tool department. It is also desirable for the supervisor of the tool department to be familiar with the requirements of the apparatus design engineer. At East Pittsburgh the tool department and apparatus design department are in very close contact.

Summary of Advantages

Some of the advantages that are obtainable from welded tool and jig design are:

Simplicity of Design — A tool designer does not have to consider casting difficulties generally entering this class of work. In the old days, good design would frequently be sacrificed to cheapen the pattern and casting cost on work requiring only one or two castings.

Elimination of Defective Castings — Since the fabricated jig is built from hot rolled or structural steel, we have no difficulty with defective castings.

Adaptability — The tool or fixture can be changed at any time, during its construction or after its completion.

Strength — The tool or fixture, since it is made from steel, is unbreakable.

Permanence — From all our tests, the tool or fixture "stays put" and retains its size and shape throughout its life.

Lightness — The tool or fixture is considerably lighter, due to the use of material of greater strength, thus eliminating the extra material, and that which is usually found in a casting due to pattern draft.

Low First Cost — After repeated checks, we find that costs are lower. Our investigations indicate that drill jig bodies cost approximately 40% less than cast iron, while milling fixtures are about 15% cheaper than formerly.

Low Maintenance — Maintenance costs of welded steel fixtures are about 15% that of equivalent devices made of iron castings.

Aluminum Alloys In Transportation

By W. HOLZHAUER
Pacific Coast Foundry Division
Aluminum Cooking Utensil Co.
Oakland, Calif.

SINCE IT COSTS MONEY TO MOVE dead weight, the trend in the transportation industry is toward the elimination of non-productive weight. By reducing the weight of a car, bus, truck, or plane, faster schedules can be maintained, the pay loads can be increased, and the operating costs materially decreased.

Aluminum has played an important part in this weight reduction campaign. In alloy form, aluminum possesses the strength per square inch of cross-section that structural steel has and can be used in place of the heavier materials without sacrifice of safety. Its low specific gravity, its high heat conductivity, its resistance to corrosion, and its ability to absorb impact loads without distortion make it well adapted to meet the requirements of the transportation engineer.

Pure aluminum is a soft metal, quite ductile but not very strong. Its use in various types of machinery has been effected by means of a number of alloys, each one characterized by certain properties, which fit it for definite uses. Since these have all been frequently described in various places, and room for systematic treatment is lacking here, further remarks will be confined to a few generalities.

Casting and Piston Alloys

One composition has been used for many years (known as No. 12 or S.A.E. 30 — essentially 8% Cu in 92% Al) for castings in which the requirements of tensile strength and ductility are moderate (on the order of 22,000 lb. per sq.in. ultimate strength in tension and 2% elongation in 2 in.), and where it is desired to keep the cost as low as possible. Small additions of silicon and iron or zinc to this alloy improved the original binary alloy in machinability, tensile strength, and casting characteristics. Either No. 12 or a variation of it is frequently the material chosen for crankcases for truck, bus, and marine motors, for oil pans, radiator shells, and transmission cases.

Deficiencies of ductility and of casting properties of the above have been remedied by the aluminum-silicon alloys, either plain or "modified." Silicon (4.5 to 6.0%) decreases the hot shortness. On account of these casting characteristics and its resistance to corrosion, this type is frequently specified for marine fittings, auto-

Where Weight Is Limited by Highway Laws, Maximum Pay Load Is Secured by Aluminum Dump Bodies. This one yearly earns 3 times its extra cost

Photo by Rittase

mobile and bus body castings and instrument containers.

Both the above families of compositions are used in the condition as cast. Materials of higher strength are required for heavy duty engines for fire apparatus and motor buses, and for aircraft engine parts. Aluminum has thermal properties which have made it standard material for air-cooled aircraft engine heads and it is even found on some first class water-cooled motors. For these a 4% copper alloy with the "normal impurities" silicon and iron under definite control at fractional percentages is available. It is known as No. 195 or No. 196, depending on whether it does not or does contain 0.2% magnesium, and can be heat treated to tensile strengths ranging from 28,000 to 50,000, corresponding to Brinell hardnesses of 50 to 110, and elongations of 12% to 0.1%.

Advantageous use of aluminum alloys for pistons is proven when it is known that over 60,000,000 pistons have been produced by a single manufacturer. Alloy No. 122 (S.A.E. 34), containing 10% copper, 1.25% iron, and 0.25% magnesium, was developed about 15 years ago primarily for pistons cast in permanent molds. Its essential characteristics are high tensile strength at elevated temperatures, resistance to wear, and good casting qualities.

There has been a demand for some time for a light alloy piston which had a coefficient of expansion more nearly equal to that of the cylinder in which it operates. Many methods have been devised to compensate for the greater ex-

passivity of aluminum, but these have been in the design of the piston and the use of inserted struts. The development of a low expansion piston alloy containing silicon, nickel, magnesium, and copper strikes at the fundamental cause for large clearances, removes all susceptibility to permanent growth by preliminary heat treatment, and permits a much closer fitting of the piston than was possible with the older aluminum piston materials. The expansion coefficient of this alloy is 0.0000105 per degree Fahrenheit between 70 and 212 F. — 15% less than the older piston. Being about 10% lighter it is especially desirable for aircraft engines. Difficulties in machining have been removed by using tungsten carbide tools.

Heat Treated Wrought Alloys

Important as these cast alloys are, engineers have been given the choice, within the last few years, of an imposing array of compositions which can be had in extruded shapes, rolled sheets or sections, or forgings.

There are two classes of wrought alloys: First, those which are hardened by cold working but cannot be hardened by heat treatment; second, those which may also be hardened by heat treatment. The wrought forms of the first class are produced principally from commercially pure aluminum and from an alloy containing 1.25% manganese. Complex alloys of the duralumin type characterize the second class. A comprehensive table of their mechanical properties was given as a data sheet in METAL PROGRESS in the November, 1930, issue on page 81.

Development of duralumin and of the heat treatment of aluminum alloys began in Germany about 20 years ago. It was the means whereby the genius of Count Zeppelin was enabled to produce the rigid dirigible whose most recent example is the U.S.S. Akron. Today there are several aluminum alloys of the duralumin type, generally called "the strong aluminum alloys."

The alloy known to the American trade as 17S is substantially the same as the original duralumin, and contains approximately 4% Cu, 0.5% Mn and 0.5% Mg. Immediately after a solution heat treatment its tensile strength is about 45,000 lb. per sq.in. with 18% elongation. On standing or "aging" at room temperature for several days the alloy develops a yield point of 35,000 and tensile strength of 60,000 lb. per sq.in. with a slight increase in elongation.

Immediately after quenching and before aging sets in, considerable mechanical work can be done, such as bending, upsetting, or forming, and this is the usual routine of fabrication. The alloy finds very wide use in aircraft construction and in structural shapes for truck bodies, street cars and railroad coaches — to mention only major items in the transportation field.

For high strength members of recently constructed airships the yield point has been improved by about 5% reduction by cold work

Wherever the Idea of Low Weight for High Pay Load Is Pushed to Its Limit, There Will Be Found Much Aluminum and Its Alloys. In suburban service, especially rapid acceleration means faster schedules, higher traffic density

immediately after heat treatment. Reported values are then on the order of 50,000 yield and 15% elongation.

An equally strong alloy containing about 4% Cu, 0.75% Si and 0.75% Mn was developed by Jeffries and Archer in 1920 to provide lower first cost, easier melting practice, and greater workability. It is known as 25S and has been used extensively in the manufacture of connecting rods for all types of internal combustion engines. Side rods of a small locomotive and motion links for some very large ones are performing satisfactorily. Practically all of the aluminum propellers for airplanes used today are forged from this composition.

The above alloy requires an artificial aging at a slightly elevated heat. For drop forged connecting rods the heat treated strength is about 60,000 lb. per sq.in. Rods made from this material have a sufficient allowance for stiffness and strength and save about 50% of the weight which reduces centrifugal force on the crank pin bearing and minimizes vibrations in the crankshaft.

Other forging alloys of exceptional workability, containing 0.6% Mg and 1.0% Si, more or less, are marketed under the names Aldrey, Almelec, or 51S. The exceptional workability of this alloy allows the forging of crankcase halves for radial engines and forged nose pieces for aircraft engines which would have been almost impossible in any of the other strong aluminum alloys.

Structural Application

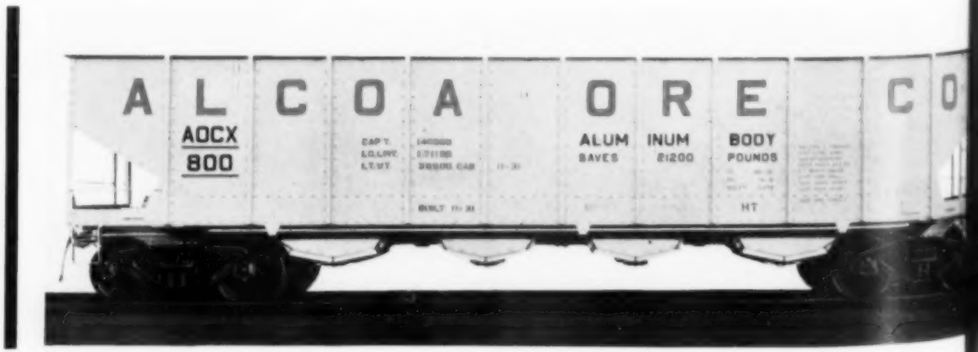
In replacing heavier metal with the aluminum alloys, there are certain things to consider. In some instances, it is necessary to use a greater cross-section for the aluminum alloys because of the fact that their modulus of elasticity is lower than that of steel. Even with such modifications in design there is still a considerable saving in weight effected by the use of the strong light alloys. For instance, a rectangular beam of the same width as steel is equally stiff and twice as strong when it is 44% thicker. Its weight, however, is only half that of steel.

Such facts as these have turned designers' attention toward the application of the strong alloys to the structural parts of automobile buses, trucks, and railroad and subway coaches. In one recent design of automobile bus for city service, one-quarter of the weight of the body is of light alloys. Seat brackets, pedestals, front frames, and radiator shells are commonly installed details.

Coal and Coke Truck Bodies

The use of sheet plate and structural shapes has been extended to the fabrication of dump truck bodies for coal and gravel. Pittsburgh Coal Co. of Pittsburgh and Minneapolis, has had excellent satisfaction, the light metal having stood the gaff of heavy haulage for nearly 4 years without showing any evidence of failure. Over-all dimensions of the 2-ton coke bodies are 8x5x3 ft. high. Capacity is 4.25 cu.yd. Weight of the body is 605 lb., as compared with 1250 lb. for a suitable steel substitute.

Both the sheet for the body and the structural frame were fabricated from the strong aluminum alloys. The only iron parts in these bodies were hinge-straps, hinge-bars, chain, chain anchors and sliding door handles. Only two structural members of each body required hot forming, so the bodies were ready for assembly at the end of the second day's work. No



Aluminum Is in Common Use for Tank Cars for Transporting Corrosive Chemicals, But Only Recently Has It Been Adopted for the Punishing Service a Dump Bottom Car Receives

difficulty was encountered in bending the 6-gage sheet on a radius of ¾ in. Such bodies are mounted on Ford and Chevrolet chassis, and save much in truck maintenance, tire replacement, and general operating expense.

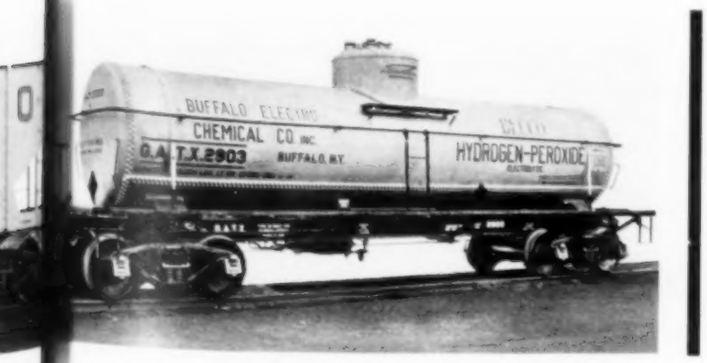
For the greatest operating economy it is usually necessary to utilize the maximum gross load permitted by the state laws. Such was the principle governing the design of dump car bodies, 16 cu.yd. capacity, mounted on a six-wheel chassis, for the Seaconnet Coal Co., Providence. The truck complete weighs 15,550 lb., and since the maximum gross load for vehicles of this type in Rhode Island is set at 40,000 lb., it has a useful load of 24,450 lb. Had the heavier materials been employed the pay load of the truck would necessarily be limited to 22,425 lb. (a loss of one ton) and the capacity of the truck to 15 cu.yd. While the aluminum alloy sheet and structural shapes cost more than similar sheets and shapes in steel, the increase of 2025 lb. in pay load is sufficient to net a yearly return of 337% on the additional first cost.

Railroad Rolling Stock

There are other applications in which light alloys have lowered the cost of transportation, since propulsion energy for street railways costs between 5 and 10¢ per lb. per year. Many street railways have materially decreased the weight of their rolling stock since the Cleveland Railway, the Chicago and Joliet Electric Railway, and the Springfield Street Railway pioneered the use and application of aluminum in stressed members of street car frames six or seven years ago. These applications of aluminum have reduced the weight of the cars as much as 30%, and a 30% reduction in dead weight makes a substantial yearly saving in propulsion energy.

According to an article by A. M. Robinson in METAL PROGRESS for October, 1930, the first use of aluminum was for interior finish, molding, window panels, and fittings in a lot of 300 motor cars and trailers built for the New York subway in 1904. This great underground transportation system has followed this practice consistently since then. The latest types of quick-loading cars for the Eighth Avenue subway were studied carefully from the weight saving standpoint in order to bring the wheel loads on these 280-passenger units within the limits of the East River bridges. Lower deck head lining, doors, seat boxes, and lower swing-sash panels are made of aluminum alloy sheets. Most of the door-operating devices and much of the automatic control equipment are also made of the light alloys.

Trunk railroads have also turned toward the light, strong alloys in order to decrease the weight of their rolling stock. The most notable applications at the present time are in suburban motor cars and trailers. In 1926, the Pennsylvania Railroad constructed eight aluminized cars, saving 13,100 lb. of weight per car; in 1927, the Chicago & Northwestern built 120 cars, and in 1929, added 25 more "aluminized" units; the Illinois Central began with 25 cars for its Chicago suburban lines nine years ago, added 215 cars to its system in 1926, and 20 cars in 1928; and the Northwestern, in 1929 and 1930, built 20 cars with many aluminum parts. To date, 778 cars containing applications of light metal in one form or another are in operation on 15 different railroads.



Tank Cars 5 Tons Lighter

While the use of aluminum in passenger car construction possibly represents the railroads' largest consumption at the present time, its use in tank cars should not be overlooked. Between 75 and 100 aluminum tank cars are in service on American railroads transporting such commodities as glacial acetic acid, formaldehyde, and hydrogen peroxide. These cars save between four and five tons dead weight, and because they resist attack by chemicals and food products, there is no danger of the commodity becoming contaminated.

NY 32
FX 24·90

Stainless Versus Chrome Plate

As Told By
Auto Builders To
JOHN G. MAPES

. . . AUTOMOBILE BUILDERS have chosen greater values instead of lower prices as the keynote of 1932 sales campaigns. Throughout the industry emphasis is being laid on innovations in design and equipment: Free wheeling, floating power, syncro-mesh transmission, stream-lined bodies, six cylinders at the price of four and eight for six! Rigid economies are required to provide these at no increase in price; the manufacturer's profit is also usually reduced.

Obviously, therefore, 1932 models cannot carry unnecessary manufacturing costs. If an expensive material can be replaced with a cheaper one at no sacrifice in serviceability or appearance during the expected life of the car, most manufacturers make the substitution. If a change in design or manufacturing process will mean even a small saving, the change is likely to be made. Where, then, do the stainless steels fit into the picture?

Unquestionably, resistance to corrosion and staining is important. Further, many manufacturers recognize that stainless can be drawn or rolled according to most of their present specifications with little difficulty. But who will stand the cost of the expensive alloy? Certainly not the public — at this time — and certainly not the car builder (whose profit margin is often far too slim for his stockholders).

The present depressed copper market and low cost of brass, coupled with improvements in plating technique, have made chromium plated brass the purchasing agent's most frequent choice for bright work. Aluminum, chromium plated, is used by some car builders. Deep drawing steel sheet, plated successively with copper, nickel, and chromium, has been found most economical for radiator shells.

Ford Likes Stainless

Not all manufacturers agree that stainless nickel-chromium-iron alloys are too expensive for wide use. Two years ago Ford Motor Co. began to use material of the 18-8 composition for radiator shells, cowl mouldings, head and tail lamps, and windshield stanchions. A chromium-iron alloy containing 16 to 18% chromium was used for hub caps and door handles.

Until this change to stainless, Model A's had been nickel plated. Nickel was not satisfactory for tarnish resistance, so chromium plating was extensively investigated. The apparently uncontrollable pitting and peeling of a low cost chromium plating job led to the final selection of stainless sheet. The cost increase was absorbed by the company.

Head lamps, radiator shells, tail lamps, and windshield stanchion are formed from strip at Ford plants. To avoid scratched dies and to prevent the strip from sticking to the die, a drawing compound composed of lithopone, sulphur, talcum powder, and No. 2 cup grease, thinned with lubricating oil, is used. The sulphur acts to scour from the surfaces of the dies

Ford Model A's Pioneered the Use of Nickel-Chromium-Iron Alloys for Almost All Brightwork Parts

the slivers worked up by the scratching action of the stainless. Otherwise, these tiny slivers would roll up, leaving fairly large furrows in the die like the tracks left by a snowball rolling down hill.

Ford hub caps, cowl lamps, door handles, and, quite recently, radiator shells are made by supply houses. The hub caps and handles can be formed from the less expensive 16 to 18% chromium-iron, because they are located far enough away from 18-8 articles on the car that the slight difference in color is unnoticeable. When the radiator shells are made by the supply house they are rolled from strip rather than drawn because rolling equipment was available there and tests showed that rolled shells were just as good as drawn shells.

Packard Picks Chromium Plate

Cost is not the deciding factor at Packard Motor Car Corp., yet chromium plating is preferred there to stainless steel. The bright work on Packards is polished and buffed to mirror-like perfection, and chromium plate will readily take this finish where stainless will not.

Another disadvantage Packard finds is that the use of stainless necessitates numerous limitations in design which can be avoided by the use of other materials, such as zinc die castings or stamped brass, which can be easily plated. The contrast between the color of the plated ware and stainless steel is likewise an objection.

Wheel spokes on Packards are made of stainless, however, to resist splatter from salt-covered streets in winter and other corrosive conditions. Even these, though, are chromium plated to maintain complete color harmony. Packard's requirements for chromium plate are such that an even deposit of metal, free from pits, is assured.

Only the cowl beading on Studebakers is made of rustless iron, for the Studebaker Corp. favors chromium plated material because of its lower cost and more brilliant color. Rustless iron is chosen for the cowl beading, however, because this part is directly in the driver's line of vision and rust spots on it would have a bad psychological effect. To maintain a uniform color among all bright work pieces, the cowl beading is chromium plated.

Wheel spokes, bumper and bumper bolts, head, cowl and tail lamps, door handles, and radiator shell are all plated with chromium to exact specifications and highly polished. This finish has proved to be quite satisfactory.

Popular Demand Is Lacking

Hupp Motor Car Co. has never offered any type of stainless iron alloy as standard equipment because of its high purchase price and because it is more expensive to fabricate. A survey made recently indicated that the final cost of stainless cap screws and bolts was three or four times as much as the cost of ordinary steel bolts, chromium plated.

On the large eight-cylinder Hupp models the objection of increased cost would be immediately waived if the public demanded stainless steel, and stainless would be quickly and willingly used. This demand can hardly be said to exist today, although there is no doubt that people are becoming more "stainless conscious." Increased popular demand for the material, brought about by advertising, and lower cost to the automobile builder would put stainless on all Hupp models.

Buyers of Hupmobiles, it is believed, would make no distinction between the color of a chromium plated brass cowl lamp and one of stainless steel. Some of them now exercise the option of stainless steel spokes in preference to enameled spokes, particularly when the body is finished in a dark shade.

Another car company believes that stainless steels must go into direct competition either with plain carbon steel successively plated with copper, nickel, and chromium, or with chromium plated brass or aluminum. Ultimate cost to the car builder is at present the deciding factor.

Both stainless steel and chromium plated brass and aluminum are specified for runningboard moldings, cowl beading, hood hinges, and gas tank caps, and, on occasions, all of these have been of stainless because of prevailing lower prices. All these parts are manufactured by supply houses according to strict specifications. Stainless is consistently the cheapest for runningboard moldings. Company engineers believe that, generally speaking, it is cheaper to roll long, hollow sections from stainless strip than from either aluminum or brass, when the cost of chromium plating is added to the last two materials.

A number of exposed bolts such as bumper and similarly prominent bolts are made from malleable iron, which does not plate well. These bolts have a stainless steel shell sprung on them.

Engineers of this company think there is not enough demand for stainless to justify the extra cost. Moreover, it is not readily adaptable to such parts as radiator shells because of the difficulty which would be experienced in drawing the intricate shapes popular today.

From a strictly utilitarian standpoint, these engineers would prefer to adopt stainless for frames, cross-members, and rivets. Proper designing would assure a suitable strength-weight ratio and the body would be proof against the corrosion of calcium chloride, salt spray, and other enemies of ordinary steel.

Pierce-Arrow Motor Car Co. adopted stainless steel because it seemed more permanent and therefore less expensive than competitive materials. Nuts, bolts, and screws which are exposed to the corroding effects of the weather are made from stainless to assure longer life.

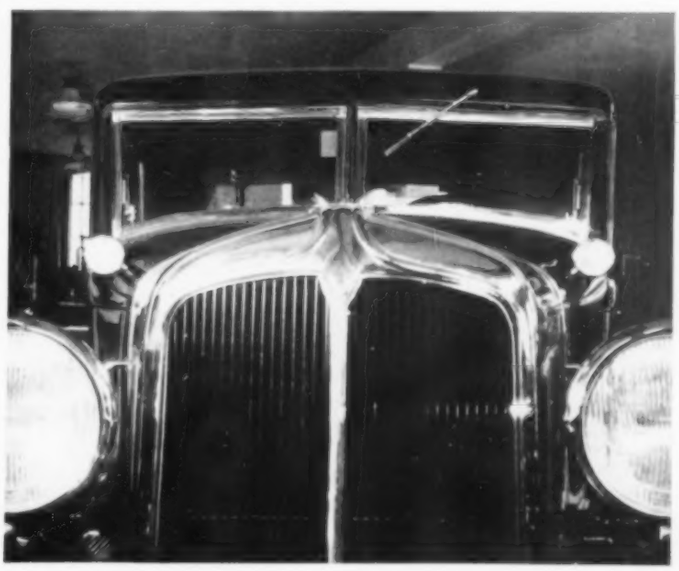
Cowl Beading on Studebakers Is of Stainless. This wheel is of ordinary steel, welded and chromium plated

Other Pierce-Arrow parts of this material are the windshield frame, cowl molding, gas tank cover moldings, hood hinge cover, door bumper striker plates, body pillar finishing plates, and luggage carrier grid bars.

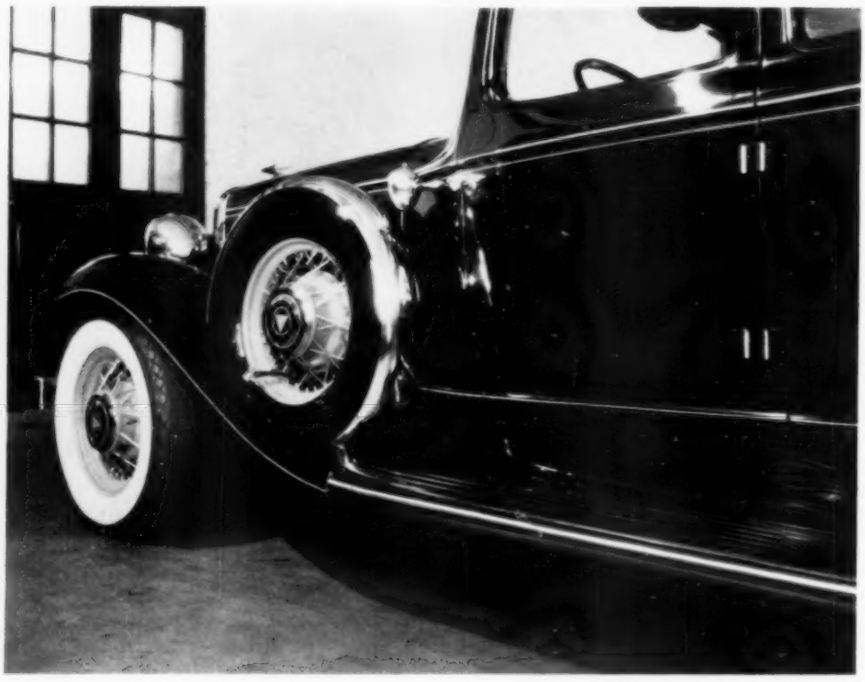
Another large motor car corporation uses stainless for quite a number of small parts in its several lines. Wherever stainless is used it is because it is the least expensive at the time.

The purchasing department is furnished specifications for stainless as well as for other

Reveals, the Bands Around the Windshield of This Model, Are Stainless



Molding Along This Car's Runningboards Is Rolled From Stainless More Cheaply Than From Brass, Chrome Plated



materials — a rather general practice in the industry. Parts which may be made of 18-8 or of 16 to 18% chromium-iron are crank hole covers, cowl beading, hub caps, and bolts for the bumper and trunk rack. On certain large models stainless is used for the "reveals," the outside window sills of closed models.

This corporation would use more stainless material if its strength were greater and if it were possible to upset it or cut it on screw machines with less difficulty. While having an open mind on the subject, the engineers feel that stainless ferrous alloys in general are high-priced products, while motor cars, especially under present conditions, must be relatively low priced.

Many of the above-mentioned companies find that the corrosion-resisting properties of these various chromium-containing alloys can be used to advantage in such places as water pump shafts and bolts in the manifold.

Except for the Ford organization, the concensus is that the high cost of stainless offsets the advantages of long life. Around Detroit the rumor is spreading that even the new model Fords will not use 18-8 for radiator shells but will select some less expensive material and chromium plate it. If this rumor proves true, the tonnage of stainless going into automobiles will be considerably reduced.

It can hardly be unfair to the automobile industry to point out that, with the exception of a few high-priced cars, the manufacturers make no pretense of producing cars that will run forever. Rather they try to produce one which will offer great value at small cost and which will become out-moded in a short time by still further advances and improvements in car building. To build a car which would last ten years would defeat the purpose behind most new models. Mr. Kettering is given credit for the thought that the research departments exist for the purpose of making people "reasonably dissatisfied with the old car."

Of course, were stainless steels sold to the public as thoroughly as balloon tires originally were or as free wheeling is now, the manufacturers would use them in greater quantities. Likewise, if the present cost of a finished item of stainless steel were comparable to one of chromium plated brass, the tonnage of stainless used on automobiles would mount, with the automobile builder probably bearing the advertising burden.

Treating Parts for Non-Uniform Hardness

. . VIEWED FROM ONE ANGLE, DIFferential or selective hardening may be regarded as an advanced practice in the art of heat treatment. It contrasts with the practices of most operators, which produce parts held within close limits of hardness, piece to piece and spot to spot on the same piece. If a part is to be hard on one end and soft on the other it would ordinarily be made a composite of a hardened piece and a softer one.

On the other hand, differential hardening is one of the commonest tricks of the toolsmith — for instance, his practice of quenching the tip end of a pick or cold chisel and then drawing the temper by allowing the heat to flow from the shank toward the end. However, the uniformity and reproducibility of such hand work is strictly commensurate with the skill of the workman, and at best the results are so variable that the plan cannot be relied upon to deliver acceptable work in quantity production.

A satisfactory solution of the problem of getting parts of variable hardness is found in the case hardening process. This, of course, gives material hard and relatively brittle on the outside, changing inward to a tough and strong core. Certain areas of the surface may be left soft by the well known expedient of copper plating those areas before the carburizing operations. Carburizing controls the hardness of a part primarily by controlling the carbon content.

Three Methods Available

Since hardening practice comprises a heating, a rapid cooling, and a moderate reheating, a single piece of steel with uniform carbon content may be given a differential heat treatment (and emerge with one desired portion much harder than another) in three ways: (*a*) Heating and quenching merely that portion which is desired to be hard; (*b*) heating the entire piece uniformly but quenching only those portions which are to be hard, and (*c*) reheating various portions of a uniformly hardened piece to a different degree, thus softening some regions more than others. Other operations are possible, but the three mentioned have been in satisfactory operation at the Rouge Plant of Ford Motor Co. in regular production. An example of each will be described, since these practices have replaced more complicated and expensive series of operations.

Perhaps the first mentioned is the most interesting, since it also involves a rarely used method of heating for heat treatment. The part is a shaft for water pump — a plain round bar 0.630 in. diameter and about 9 in. long. It is of "AAA steel," and while the ends are to be soft enough for subsequent machine operations, the central portion, where the bearings are, is to be hardened to Rockwell C-48 to C-50. (For a description of the various steels used by Ford and their specifications, see an article by J. L. McCloud in METAL PROGRESS last March, and the data sheet in the same issue. AAA steel contains carbon 0.30 to 0.35%, manganese 0.65 to 0.80%, chromium 0.90 to 1.10%, silicon 0.10 to 0.20%.)

The heating machine, as shown in the view on the next page, is built on the general lines of a resistance welder. The short shaft to be hardened is gripped at each end by water cooled jaws, operated from overhead levers. Low voltage current of high amperage, regulated by a transformer in the machine base, is switched on

by the clamping levers and is led through heavy copper cables to the jaws and thence through the shaft, which completes the circuit, heats rapidly and expands as it heats.

It will be observed that the left-hand jaws are supported by a stanchion which in turn rests on short vertical links. As the shaft expands this jaw moves to the left, and when the temperature of the part between the jaws has reached 1620° F. it has travelled far enough to the left to trip a relay which switches off the current. The operator thereupon throws the clamping levers up, lifts the hot bar (with cold ends) out of the fixture and quenches it vertically in an oil bath at 80 to 120° F. As soon as the clamps are released the movable head returns to its starting position, ready for another heat.

Heat Generated Inside Steel

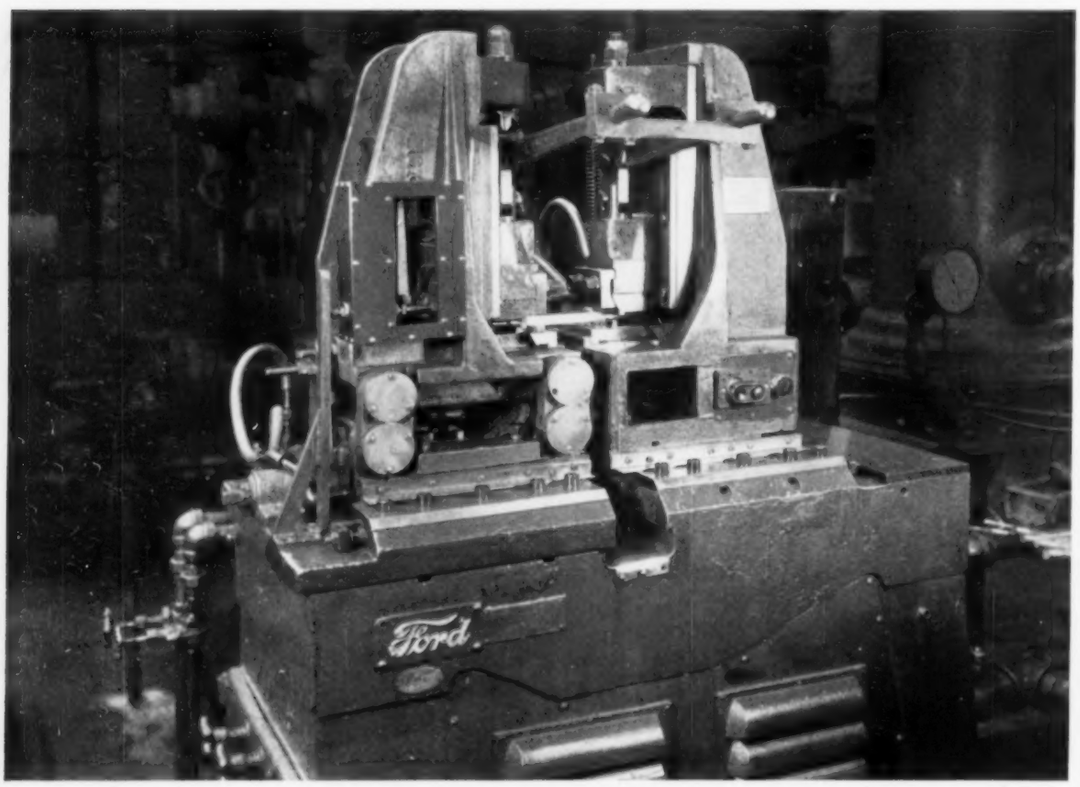
Four of these machines of Ford design and construction are sufficient to harden 600 shafts to Rockwell C-45 to C-50 in an hour. They are conveniently spaced about one quenching tank, and one man operates two machines — quenching and reloading one while the other is heating.

Subsequent operations on the shaft include straightening, grinding the bearings, cutting a keyway and drilling for a cotter pin at one end, and threading the other.

Since the heat in this "furnace" is generated inside the steel being heated by the passage of electric current, and since this current flows from one jaw to another, there is no heating on the ends which must remain soft for machining. Furthermore, the heating time is on the order of 10 sec. so there is little chance for heat to flow endwise by conduction.

When the current is first turned on the cold bar four hot spots quickly appear, one at each jaw. The glow rapidly extends toward the common center, and when the piece is ready for quenching it is uniform in color across the gap. Excessive hot spots at the jaws indicate arcing, due to poor contact between jaws and steel. At such times — perhaps twice a day — when there is danger of overheated spots and blisters on the surface of the shaft, the operator pulls the main line switch and closes the jaws on a hand-operated reamer, which clears away adhering scale. Jaws are made of a hardened copper alloy commonly used for electrodes on resistance welders, and are quite durable.

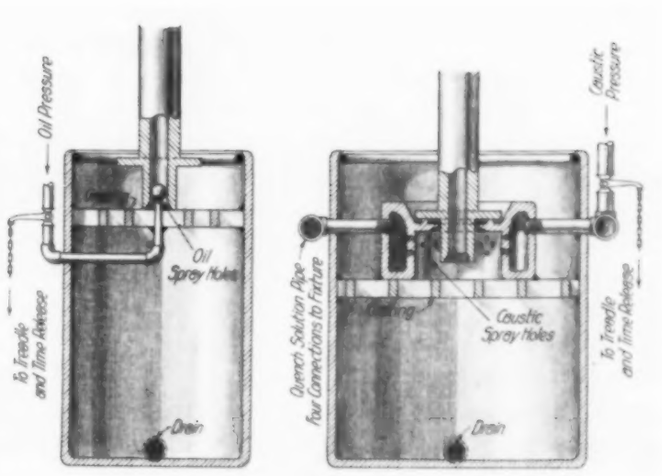
M. D. Bowen, in METAL PROGRESS last May, has described a method of hardening the ends of rails in track to resist wheel batter. Other operations of spot hardening parts, like the corners of carpenters' squares, by intense local heating by oxy-acetylene flame, may be observed occasionally. However, this job was probably the first application in mass production of electric resistance for localized heating for quenching. Obviously, this plan of differential hardening



Shaft Is to Be Hardened Mid - Length for Bearings but Remain Soft at Ends for Machining, so Central Portion Is Heated by Heavy Electric Current, as in a Resistance Welding Machine

requires very rapid heating by very intense flames or mediums in order that the surroundings will not be heated by conduction.

The second method of differential hardening involves heating the entire piece uniformly but quenching only the desired portions. One job of this sort at the Rouge plant is a camshaft; numbers of them are shown in the foreground in the view on page 50. It will be observed that it has a flange on one end — this flange is to be soft (Rockwell C-20) so it can be drilled after a treatment which produces a Rockwell hardness of C-55 on the cams and bearings comprising the most of its length. Furthermore, quenching must be done in such a way as to minimize warpage.



Sketch of Quenching Fixtures for Rear Axle Housing. Oil spray from center cools thin end without cracking; caustic spray from outside then hardens bearing surface to C-56 minimum, leaving center of bore machinable

The steel used is known as "EEE select." This is a medium manganese steel of the following composition: Carbon 0.38 to 0.42%, manganese 0.70 to 0.90%, silicon 0.07 to 0.15%. Heat treated to 525 Brinell hardness it has the following physical properties:

Ultimate strength	255,000 lb. per sq.in.
Elastic limit	245,000 lb. per sq.in.
Reduction of area	6%
Elongation	2% in 2 in.

Camshafts of this sort were the first parts to be hardened in quenching machines developed coincident with the use of medium manganese steels for crankshafts, driveshafts and camshafts. (As pointed out by Mr. McCloud in the last March issue, these steels have good hardening capacity, in oil, water or caustic solution — as required by the cross-section being quenched — and have unusual resistance to alternating stresses, probably due to the uniform gradation of hardness, surface to center.)

Rugged Quenching Machines

Essentially these machines are powerful clamps or rollers which hold the parts in correct alignment, meanwhile spinning them rapidly and forcing the quenching liquid for an accurately timed interval on the particular sections desired to be hard. Little or no straightening is necessary on the shaft after such a quench.

The illustration on page 50 shows the charging door of one of a series of identical Holcroft turret furnaces for heating camshafts to 1500° F. Cold shafts are laid on the hearth as it moves slowly past the open door; after being carried around a complete circle, they reach a door just behind the screen, are removed one by one and placed in the quenching machine across a narrow aisle. The one shown at the right of the view was designed about six years ago; recently others have been installed, much more rugged in construction, wherein the hot shaft is held in a horizontal position rather than vertically. Otherwise, the operations are identical.

A better idea of the operation of these quenching machines may be had from the view on page 51, which shows a rear axle, just before the cooling operation starts. Imagine, for an instant, that the work is a camshaft, the enlarged end at the right. The hot shaft rests on knurled flanges projecting from two parallel rollers (one shown dimly at the rear) which turn constantly, being driven by end gears meshing with the bull wheel just inside the housing. The knurled flanges bear against round portions of the camshaft, and are cut with spiral grooves to avoid slippage and also to provide proper flow of coolant.

Immediately above the hot bar to be quenched is a third roller with mating flanges,

which comes down and rests firmly against the hot spinning camshaft. It can be seen that when this occurs the camshaft will be held very firmly in line at six points along its length by rollers backed up by rigid castings. Warpage during sudden quenching is thus held at a minimum.

In the machine shown the bearings for the two lower rollers are bolted to the flat surface of a hexagonal drum. This is pivoted at each end in trunions whose center coincides with the center of large gear wheels at each end. One of these is free, and turns constantly, so that the lower rollers and the shaft resting on them are spinning, no matter whether the drum is stationary or rolling over. Another large gear wheel is bolted to the other end of the drum and, by means of a pinion drive, rolls the drum over. As it moves, various other parts of the machine come into action through suitable cams. The upper roller, for instance, is swung down (to clamp the hot work) by side arms projecting toward the rear and ending in rollers engaged in grooves cut into the end housings. Similar arms and rollers close the front housing of the machine. In the machine shown, when the drum rolls over, the hot shaft is clamped, spinning, and submerged in a caustic solution; when the cycle is completed the drum automatically stops at the loading position and the upper roller raises itself clear during the last portion of the movement. The quenched work can then be removed, a hot piece put in its place and the cycle restarted. One machine of this sort can handle 1600 parts per shift; a battery of three turret furnaces and three quenching machines has been installed in the camshaft department. Nine operators man the entire installation.

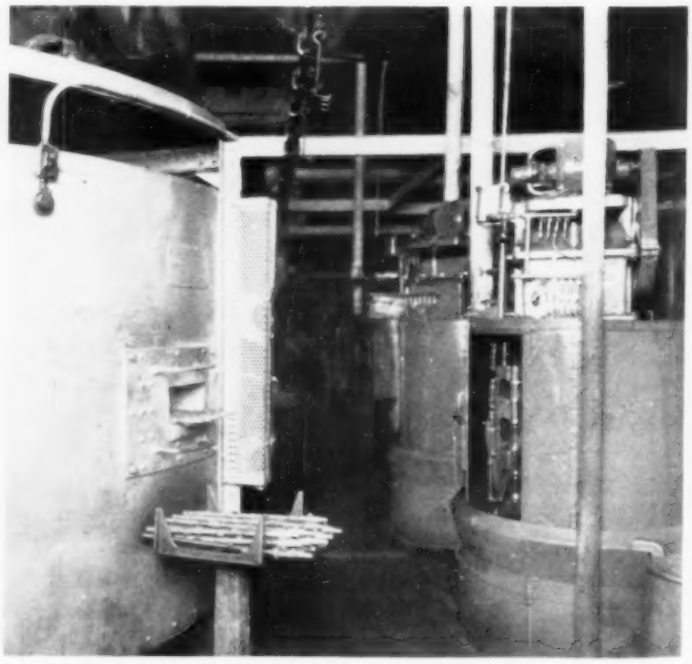
It will be remembered that the enlarged end of the camshaft must be kept soft. Since it is heated uniformly with the rest of the piece, it must be kept from the quenching solution. This is done by providing a pocket at the left end which fits the collar of the shaft neatly, and which keeps the solution out during the brief time required to quench the shaft (approximately 12 sec.). This pocket or cup is split; one half is fixed to the drum, and the other half to the upper arm, the two making a close, water-tight fit when the machine closes. Bare clearance at the opening for the neck of the camshaft permits the latter to be spun in the correct manner.

After quenching, the camshaft is immediately transferred to a barrel of cold quenching solution and hung vertically therein, with the level of the solution just below the under side of the flange. Here it is left until the hot end cools off — an expedient necessary to avoid drawing the temper of the bearing and the cam near the end flange by conduction of heat from the latter.

Little or no straightening is necessary, despite a grinding allowance on cam and bearing surfaces of 0.020 in.

Quenching fixtures of this sort may be varied in their action. For instance, submersion in the solution may be supplemented or even supplanted by jets of quenching fluid directed against regions desired to be extra hard. In fact, the early machine illustrated in the view

Rotary Turret Furnace Heats Camshafts and Quenching Machine at Right Cools Them in Caustic Spray While Spinning Rapidly Between Clamping Rollers. Flange at end is protected and remains machinable



on page 50, wherein the camshaft is held in a vertical position, operated entirely with sprays. The rear axle shown in the more recent machine has a small stream of coolant directed at the root of the gear, forged integral on the end. This starts the cooling, and "softens the shock" of the quench at this point, where otherwise quenching cracks would develop.

Hard Outside, Soft Inside

A desirable variation in hardness can be secured by proper design of the quenching sprays. An interesting illustration of this principle is the method for hardening the rear axle housing of the Ford car. It is a tube with an upset flange near one end, and the tube wall at the very end is not more than half the thickness that it is nearer the flange. The problem is to harden the housing back as far as the flange (for bearing) to a minimum of Rockwell C-56 without cracking the thin end. The inside of the tube should also be relatively soft.

For this piece "EE steel" is used, as also for the rear axle mentioned below. It is a medium manganese steel of the same chemical specifications as the camshaft except the carbon is two points lower (0.35 to 0.40% carbon, 0.70 to 0.90% manganese). Its approximate shape is shown in the sketch on page 49.

This housing is hardened by heating the bearing end only in a cyanide bath. It is then slipped over a fixture which sprays oil, from the inside, on the end of the bearing for 3 sec. up ½ in. from the edge. Since this section is of only about half the thickness of the rest of the bearing, and is not to be hardened to maximum hardness, the oil quench is sufficient. It also prevents cracking.

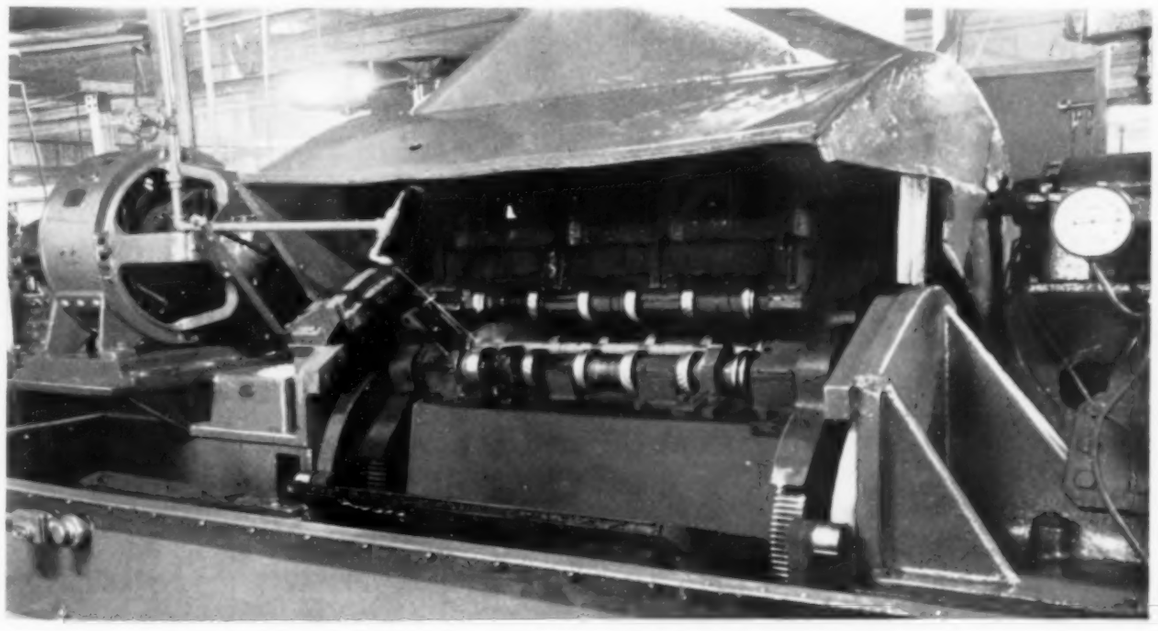
The piece is immediately transferred to the second spray quench — caustic solution under pressure, striking the outside of the bearing only for a period of 15 sec. This hardens the outside of the bearing to a depth of about 0.100 in., while the inside surface remains relatively soft, since no coolant reaches the center of the bearing sleeve in this second fixture.

Hardness tests are made on each bearing at three places, and satisfactory production is maintained by the simple expedient of putting the kind of coolant where you want it for the proper time.

Drawing to Different Degrees

Reverting again to the rear axle, shown in the fixture below. It is treated in a manner

Quenching Machine Holding Work (a Rear Axle Shaft) in Horizontal Position. Shaft has just been placed on lower rollers; upper roller comes down and presses tightly against spinning hot work as drum rolls over and submerges everything in quenching fluid

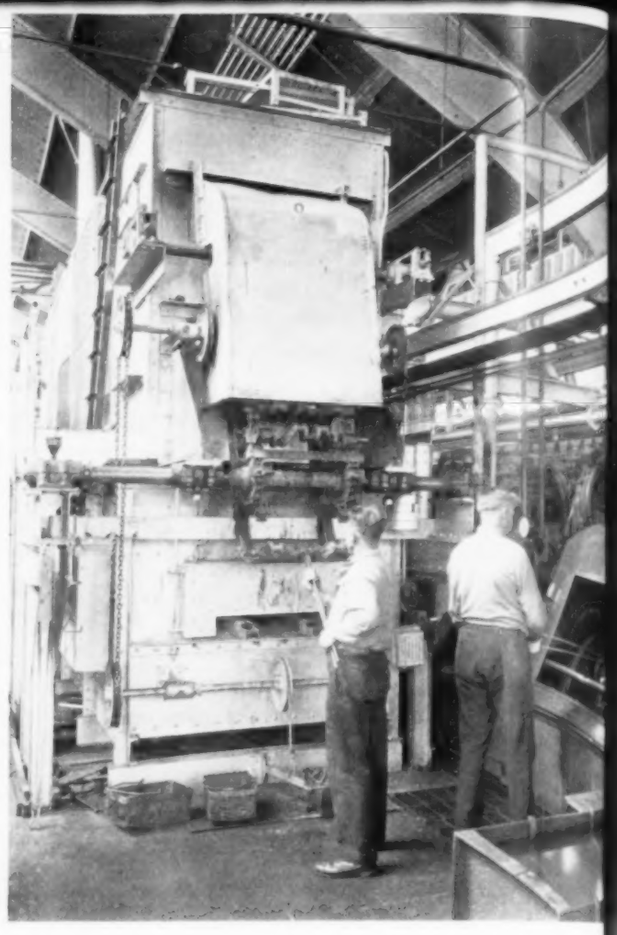


indicative of the third variety of differential heat treatment noted at the outset, namely, quenching uniformly hard all over, and then drawing to different degrees. The axle is made of "EE steel," a medium manganese steel of the same chemical specifications as the axle housing. This shaft has a differential gear upset-forged on its end; the other or wheel-end is tapered. Three separate limiting conditions are to be met — maximum hardness for wear on the gear teeth, somewhat less hardness on the shaft to give good wear on bearings but tough against torsional stresses, and a softer tapered end at the wheel hub which can be slotted easily for a keyway.

Two-pass furnaces and quenching machines are utilized in the production of this important part. One trip through the heating chamber delivers shafting at 1450° F., ready for quenching. After being spun in caustic solution (10° Beaumé, at 85° F.) the entire gear has a substantially uniform Rockwell hardnes of C-55 to C-57. It is immediately transferred to the furnace conveyor, which on its return trip carries the shaft sidewise through a chamber *under* the heating hearth.

This tempering chamber is in fact a triple chamber, being divided by longitudinal partitions extending down from the roof and up from the floor, providing just enough clearance for the shaft. One of these chambers, at the left side, is heated by radiation from the heating hearth overhead, and sidewise from the other channels. Its temperature is 600 to 620° F., sufficient to deliver the gear hub at Brinell hardness of 477 to 512. The central longitudinal passage has a heating element in its floor which maintains a heat of 725 to 740° F. in the compartment, thus drawing the mid-length of the shaft somewhat higher to a Brinell hardness of 402 to 444. The other end has a more active heating element on its floor, which generates a temperature of 900 to 950° F., and softens the tapered end to 302 to 340 Brinell.

The final half-tone shows one of the triple deck furnaces wherein radiation from the heating hearth is used for the tempering operation. The part being treated, however, is the Ford Model A crankshaft. Here the lower hearth, about waist high, is the heating hearth. Crankshafts are pushed through from the far end; the shafts ride on rails whose projecting ends can be seen. Hot shafts are transferred by hand to the quenching machine at the right, and thence to the upper part of the conveyor just above the operator's head. This conveyor chain carries them up, through a preheating hearth just under the furnace roof, thence back to the discharge end through a passage just over the heating hearth. Coming out the near end they are released by their carrier and drop down into the curved bracket. The second operator is shown lifting one of them aside to pass it on to the next operation.



Triple Deck Furnace for Quenching and Drawing. Hot shafts are taken from lower deck to quenching machine, thence to holders on the chain belt which carry them up and back to the furnace. The operator is about to remove a completely treated crankshaft

In conclusion, a safety-first note about the caustic solution may be valuable. At each quench tank there should be a bottle of vinegar and a pad of bandage in a small cabinet, so if a man gets a drop of it in his eye he can neutralize the alkali promptly. Quenching machines should be adequately hooded, to prevent splash and also to draw off steam; then such minor accidents will be rare. Prompt treatment with vinegar will avoid serious mishap.

Editorial

? What Is a Metallurgist

NOWHERE is the changing meaning of the word metallurgist more apparent than in the automotive industry. At a recent meeting in Cleveland, T. H. Wickenden looked back to 1913 in Detroit, when W. P. Woodside organized the Fellow-Craft Club of 18 foreman heat treaters for the discussion of common problems, and he (Wickenden) and C. N. Dawe sat on the other side of the table to supply some scientific information now and then. The automotive industry had become convinced that cars should be made of light, strong parts, and many were the resulting troubles. Some bright young chemists and mechanical engineers were forthwith impressed into the service, frequently with the title of "chief metallurgist," and as frequently resulting in a situation where the blind led the blind.

Dictionaries, which record usage as of a generation ago, say that a metallurgist is a man skilled in the art and science of ore concentration, metal smelting and refining. He knows about production, rather than consumption. Obviously, this is not a very good intellectual background for a trouble shooter in the forge and heat treat department; nevertheless, no other word seemed to be handy to distinguish this new technologist becoming so important to the consuming industries.

As years have passed, the discrepancy between title and function has increased, until the word metallurgist has come to mean "metal specialist." Of course, a person can specialize in one of a number of different phases of a subject, which thought leads directly to the opening statement — that this metal specialist has particularly interesting and valuable functions in the automotive and related industries.

When a large quantity of machinery is to be produced wherein weight must be at a minimum, the highest skill is required both on the part of the designing engineer and the production man. Nevertheless, it is still true that the designer generally knows little about the shop man's problems, nor does the shop superintendent do much more than marvel how a designer could think up something so difficult to make! The metallurgist (in the automotive industry, at any rate) is the one man in the organization who can act as a go-between, the one man who can interpret the production limitations of a metal or a machine tool to the designer, and can tell the shop foreman why it is necessary to make the part to the given specifications.

Machinery in which weight saving is a small factor need not necessarily be crude in design, but crude design has a greater chance of operating successfully under these conditions. The size of parts may be such that the localized stresses produced by undercuts, sharp changes in sections, and keyways in full sized shafts may be disregarded with impunity. The properties of the materials used may also vary over a wide range and yet the machinery will operate for a satisfactory time.

How different is the story when minimum weight is essential! Stresses must be analyzed, generous fillets used, undercuts and threads on highly stressed parts avoided. Splines on enlarged sections of a shaft supersede keyways. The necessary rigidity of the part must be maintained by clever design, since the metallurgist has not yet learned the secret of changing the modulus of elasticity of steel. These things concern the designer.

The shop superintendent must look out for other things: The finish of the part becomes

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essential — rough finish and scratches must be avoided. Sharp, tough metal must be cut at a high rate of speed.

In turn, the metallurgist must aid in the selection of metal which responds readily to heat treatment — deep hardening properties must be considered to insure uniform properties throughout the piece and in every piece. Materials must be introduced capable of resisting high stress, great impact, and heavy wear. More than all, he must act as a go-between, across the gap from drawing room to shop.

In this changing world, nothing seems to change faster than the information expected of the metallurgist. He is still an expert in metals, but no longer does the term refer merely to a super-chemist in an open-hearth plant or copper smelter. He has penetrated into all industries where the discovery has been made that it pays to give attention to the metal being used. Somewhere in such a plant is a man who is interested in good metal as a raw material and what he can do with it. For lack of a better name, that man is a "metallurgist," no matter what his other duties are, or what his title implies.

Copper Wrenched From the Jungle

MEN who know something about the production of copper have noted the rising importance of the mines in central Africa until they have acquired the dominating position in the world industry. All of the recent plans for the "stabilization" of the copper market have awaited the acceptance by Union Minière du Haut Katanga, because of that company's ability to produce an almost overwhelming amount of metal at the lowest cost.

Few of them realize, however, that this situation is the result of studies dating back nearly 20 years, and a development carried through in the middle of a tropical jungle. How serious were the difficulties may be guessed from the statement that because of the nature of the ore, the expense of fuel, the inefficient labor, and the distance from market, ore containing at least 14% copper is needed before it could be smelted in a blast furnace at Katanga at a profit. (Under the worst conditions to be met in the United States, ore containing approximately 5% could be smelted direct if it could be found!)

Prior to the War the owners of the mining concessions in the Belgian Congo recognized that there was comparatively little of this extra rich 14% ore available, yet there were untold amounts of ore containing about half as much. This would be a veritable bonanza in America, but over there it was just so much rock. So they employed an American metallurgist, A. E. Wheeler, to show them how to work it.

At that time there were three general methods in use for the treatment of low grade ore deposits. Oldest was the method of water concentration, in jigs, tables, and similar machines, utilizing the fact that heavy mineral and lighter gangue settle at different rates. Such methods gave very poor recovery because the copper compounds in these ores had about the same specific gravity as the waste. Another rather recent method was flotation, whereby a particle of mineral was made to ride a gas bubble up into a froth, but since only sulphide minerals could in this way be floated (in the then state of the art) and the African ore was entirely oxidized, this method was inapplicable. That left the third alternative, which was leaching.

Even before the War leaching was being extensively applied at various places in North and South America to low grade oxidized or roasted ores (less than 1% copper). Usual practice was to fill a series of huge tanks with the ore and allow a weak solution of sulphuric acid to percolate through, taking the copper into solution. A leached mass of ore would be washed clean of liquor and taken to the dump; the copper was then recovered from the solution.

Unfortunately for Mr. Wheeler, he found that the African ore contained so much clay-like material that percolation-leaching was impossible, and the sludges could not be filtered. There were no sulphide ores or sulphur within a thousand miles with which to make the necessary acid. Large quantities of electric power

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were necessary, and none was to be had. No building materials were available, not even timber. No one in Africa had ever seen an ore-leaching plant, let alone operated one.

That these all but insuperable difficulties were finally surmounted, and a self-contained leaching plant, tank house, acid plant, and furnace refinery erected, capable of making about 70,000,000 lb. of copper a year at extremely low cost, is a tribute to the resourcefulness of the American engineers and to the courage and perseverance of the European owners of the property. It was a happy combination of minds, for while we willingly concede that all Yankees are ingenious, few of our native business organizations would have the far-sighted courage to pursue steadily an expensive developmental program for 15 long years. The result is a triumph of research, engineering, and finance over refractory nature, and the rewards are rich.

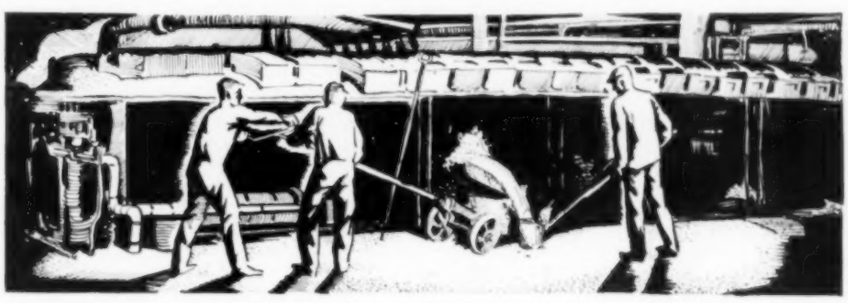
Education After Graduation

NEWS from various schools and colleges offering metallurgical courses is generally that there is a notable increase in the number of graduate students. These are men who have been working for a few years, and, finding themselves out of a job in the present business depression, are going back to school. It is a good way to avoid devastating mental depression, and the investment, if the relatively slight additional expense can be financed, will yield handsome dividends in future years.

Reports also are to the effect that such students are very apt pupils, as may readily be surmised. Each of them has found that the kit of general purpose tools furnished him during his four undergraduate years needs certain additions to fit the special line most attractive or most likely to offer future chances for success. The man, now more mature, knows much better what he can expect from formal education — he knows what he wants and goes after it and gets it. He is freed from the various distractions of "growing up" and can absorb information correspondingly faster. He has been long enough away from the sheltered life of college to appraise better the essential and discard the irrelevant.

In short, such an adult student is so much better material than the average undergraduate, that it would be a move in the right direction to add one or two years' hard labor to the present entrance requirements of a graduate school.

Contact between college students and industry has been fostered for many years and in many places by the so-called "cooperative plan," whereby undergraduates spend alternate months in school and at work in their chosen line of activity. In other schools teachers are constantly urging students to spend summers working rather than playing or loafing. However, sufficient emphasis has never been placed on the desirability of an interim between graduation from college and entrance into graduate school. On the contrary, those students who show any inclination to continue are encouraged to do so, possibly for fear that once away they will never return. As a matter of fact, those who do not return would never be missed; those who do return would be vastly better fitted for the task of acquiring specialized information for a definite vocation.



Photograph By Henry M. Mayer

Waiting to be Called

American and Foreign Automotive Steel

By THOMAS H. WICKENDEN
International Nickel Co.,
New York

. . . MODERN DESIGNERS — especially of airplanes, automobiles, trucks, or tractors — require much information about the materials which may properly be used. Engineer-designers generally spend a great deal of time estimating the stresses in a working part and molding its external form; the metallurgist must give him information about the steel or alloy which will best meet the stresses, fatigue, shocks, and wear. The metallurgist, if he is progressive, is also a source of information on the fabricating and heat treating characteristics of the metals which may be chosen.

Metallurgists, therefore, continually work with the engineering department in all stages of the design to avoid details which are extremely difficult to make in the shop. Thin walls, deep undercuts, or sharp corners (to mention only a few) may require constant care in the hardening room to avoid warping or cracking.

A fund of data about the various steels and alloys is one of the prime assets of the expert in metals. Such figures may be secured in his own plant or laboratory, or from the steel producer, or from his technical society. Care is necessary in using all such figures, for his own figures may be derived from limited experience, the steel company's figures influenced by selling enthusiasm, and the society's curves from undue conservatism.

Even when a sincere effort is made to secure the unbiased facts it will be found that the reported physical properties of a given steel — S.A.E. 3130, for instance — are influenced to a very considerable degree by permissible variations in chemical analysis, by grain size or orientation, by inclusions, by maladjustments in the heat treating equipment, and by the personal equation of the shop workman or laboratory assistant. The Society of Automotive Engineers has made some intensive studies in order to integrate these various differentials into average curves or rather "bands"; but this is another matter, itself worthy of discussion at length.

Even though the last word will never be said on the matter of strength of materials, the present excellence of machine design is in no small measure due to the accumulation of sufficiently precise information to guide the metallurgist in making a reasonably good choice of metals.

Courtesy of Moore Drop Forging Co.

Carbon steel will always find much use in machine parts where moderate strength and toughness are satisfactory. Parts of small section can be easily hardened by quenching in water, but it requires a high carbon steel and a drastic quench to secure ultimate strengths over 100,000 lb. per sq.in. in a 2-in. piece. This will probably crack the part unless it has a uniform cross-section.

If the part has a considerable variation in section, it is advisable to make it of an alloy steel and quench it in oil. On the other hand, if the shop equipment is limited to water tanks, use an alloy steel with low carbon. For instance, if S.A.E. 1045, water quenched, is necessary to get the required strength, and the parts crack, S.A.E. 3130, water quenched, may be subsituted. Or S.A.E. 3135, oil quenched, will give the strength without danger of cracking and the resulting piece will be much tougher. This is illustrated in the accompanying table.

CARBON Vs. ALLOY STEEL, 2 In. ROUNDS

	S.A.E. 1045	S.A.E. 3130	S.A.E. 3135
Quench from	1600°F.	1525°F.	1550°F
In	Water	Water	Oil
Draw at	900°F.	1000°F	1000°F
Resulting Properties			
Ultimate strength	116,000	120,000	118,000
Yield point	77,000	97,500	90,600
Elongation	22%	21%	22%
Reduction of area	56%	62%	60%
Brinell hardness	235	243	231
Izod impact	15	75	70

As a guide to the selection of steels for heavy section, the table on page 59 has been prepared, showing Brinell hardness number, corresponding strengths of recommended steels, and the quenching medium for different diameters of section. The steel noted as NiCrMo in that table has the following analysis: Carbon 0.35 to 0.40%, nickel 1.75 to 2.00%, chromium 0.60 to 0.80%, and molybdenum 0.30 to 0.40%.

This nickel-chromium-molybdenum steel is gaining considerable favor for use in heavy parts, such as rear axle drive shafts of trucks and buses. Typical properties of bars heat treated in 3-in. sections by quenching in oil from 1525° F. and tempering at 900 to 950° F. are as follows: 190,000 lb. per sq.in. ultimate strength, 165,000 lb. per sq.in. yield point, 12.5% elongation, 50% reduction of area, 415 Brinell, 27 ft-lb. Izod impact.

No discussion of automotive steels would be complete without reference to those used for gears. Gear steels occupy a field of their own and it would be impossible to give more than a very meager discussion in a short paper.

There will always be considerable difference of opinion regarding the relative merits of oil hardened and case hardened gears. The former have lower cost to recommend them while the latter have greater toughness and resistance to wear. Nickel as an alloying element increases the toughness and decreases the sensitivity to variations in quenching temperatures. This is brought out in the following data for steels oil quenched and tempered at 400° F.

TOUGHNESS OF HEAT TREATED GEAR STEELS

S.A.E. No.	Analysis	Quenching Temperature	Izod Impact	Brinell Hardness
5145	C 0.47 Cr 0.90	1475 1600	5.5 to 6.0 3.0 to 4.0	444 to 534 514 to 534
3245	C 0.52 Ni 1.67 Cr 1.00	1425 1600	10.5 to 12.5 3.5 to 6.0	514 to 540 514 to 540
3445	C 0.50 Ni 2.75 Cr 0.94	1425 1600	14.0 to 14.5 13.0 to 13.0	514 514 to 555
2345	C 0.46 Ni 3.38	1425 1600	14.0 to 16.5 15.5 to 16.0	514 to 555 514 to 578

Inspection of the above figures for nickel steel shows that full hardness is developed at low quenching temperatures, and that overheating S.A.E. 3145 and 2345 has small effect on the impact strength.

Formulas for figuring the strength of gear teeth are of small use for determining the size and permissible load of automotive gears, as the strength of the tooth is not so much a factor as its capacity to resist wear. When the unit pressures on the tooth are sufficiently low to avoid pitting the face and to avoid rapid wear, the gears are generally sufficiently strong if made of an inherently tough steel. Case hardened steels with their high surface strength and hardness may carry greater unit loads on the teeth than can oil hardened gears.

Unit pressure at the point of contact between two gear teeth may be determined mathematically, but the question immediately arises: "What is the allowable stress for proper life?"

I am of the opinion that pitting on a gear tooth is a surface fatigue failure due to repeated stressing above its endurance limit in compres-

sion. If this is true, the allowable pressure should be a function of the endurance limit on repeated stressing from zero to a maximum value in compression. Most of the available data on endurance limit are from experiments wherein the piece alternates in tension and compression, or is stressed under various amounts of tension. It has been assumed that the endurance limit under compression follows the same general laws and is of the same order of value. Available data indicate this to be true.

STEELS FOR HEAVY SECTIONS

Physical Requirements at Mid-Section		Steels and Quenches (O=Oil, W=Water)				
Brinell Hardness	Tensile Strength	1 In. Dia.	2 In. Dia.	3 In. Dia.	4 In. Dia.	5 In. Dia.
187 to 212	90 to 100,000	1035 W 3130 O or W	1045 W 2340 O	3140 O 2340 O	3140 O 2340 O	3140 O 2340 O
212 to 248	100 to 115,000	1040 W 3130 O or W 2330 O or W	1045 W 3130 W 3135 O or W	3140 O 2340 O	3140 W 2340 W	3145 W 3240 O
248 to 285	115 to 130,000	3130 W 2335 O	3140 O 2340 O	3145 W 3240 O	3145 W 3240 O	3240 O NiCrMo O
285 to 321	130 to 150,000	3130 W 3140 O	3145 O 2345 O	3240 O 3435 O	3340 O NiCrMo O	3340 O NiCrMo O
321 to 363	150 to 170,000	3140 O	3240 O 3435 O	3340 O NiCrMo O	3340 O NiCrMo O	
363 to 401	170 to 190,000	3435 O 3240 O	3340 O NiCrMo O	3340 O NiCrMo O		

For instance, an oil hardened gear steel of S.A.E. 2350 or 3250 analysis will have a Shore hardness of about 72 or a Rockwell hardness of C-52. This corresponds to a tensile strength of about 270,000 lb. per sq.in. and an endurance limit under alternating stress of about 115,000. As the stress at the tooth contact is in one direction, being from zero to a maximum value, the endurance limits under this condition would be about 50% greater, or 173,000 lb. per sq.in. Dividing this by a correct factor of safety will give a suitable designing stress.

On the above assumption, gears for passenger cars in intermittent service should have a maximum unit surface stress on the order of 160,000 to 165,000 lb. per sq.in., and for trucks 150,000. (Continuous service conditions require somewhat lower figures.)

Case hardened gears commonly test between 80 and 85 Shore hardness, which corresponds to surface strengths of 315,000 to 320,000 lb. per sq.in. Fatigue tests by Woodwine (Carnegie Scholarship Memoirs, 1924) on rotating carburized specimens with the core removed showed endurance limits of 134,000 lb. per sq.in. for the case on S.A.E. 2315 and 143,000 lb. per sq.in. for the case on S.A.E. 2512. Under compressive stress from zero to a maximum value the endurance limit on the case hardened surface would be on the order of 200,000 for S.A.E. 2315 and 215,000 for S.A.E. 2512.

For automotive transmissions with intermittent service these values have been used and figured on the stresses from maximum engine torque. For trucks, tractors, or passenger cars under constant service conditions, a suitable factor of safety should be applied. In checking these values I have been advised by the metallurgist of a truck company that 5% nickel case hardened steel transmission gears have given satisfactory wear when the unit load on the tooth contact (figured from maximum engine torque) did not exceed 225,000 lb. per sq.in., whereas at 240,000 the gears pitted rapidly. The actual loads, of course, were intermittent and would not reach these values, as there was no allowance for friction losses.

Foreign Automotive Steels

In checking over the specifications of foreign cars, one is impressed by the lack of unified steel specifications, such as we have with the S.A.E. series. Efforts are being made abroad, especially in England, to standardize the steel practice. Recommendations of the British Engineering Standards Association are given in the table on the following page.

Foreign cars use more alloy steels than is the usual practice in this country except on heavy duty units. Abroad one notes a general tendency to use steel of lower carbon and greater alloy content.

For instance, front axle centers, connecting rods, and crankshafts on passenger cars (which are generally water-quenched carbon steel in this country) contain 0.40% carbon and 0.75 to

1.00% nickel. This practice improves the hardening power of the steel, so that these parts are oil quenched. On heavy duty jobs 3.0% nickel or nickel-chromium steel is used.

Steering knuckles in this country are typically S.A.E. 3130 water quenched, or 3135 oil quenched; abroad the trend is toward 3.5% nickel or a nickel-chromium steel similar to S.A.E. 3435 oil quenched.

Foreign transmission gears show a wide variety of practice. Case hardened gears of 3.0 to 3.5% nickel, 5.0% nickel, or the Krupp analysis of 4.5% nickel, 1.5% chromium are found. Oil hardened gears are commonly made of steels containing 0.28 to 0.35% carbon, 1.50% nickel, and 1.0 to 1.25% chromium. For heavy duty the nickel is increased to 3.0%.

One practice not used in this country is the manufacture of gears from air hardening steels. A typical analysis is carbon 0.30%, nickel 3.50%, and chromium 1.50 to 1.75%; molybdenum (0.15 to 0.25%) is added for the highest results. These gears are hardened by heating to 1600° F., cooling in air, and tempering at 400° F., and show a Brinell hardness close to 500. One interesting variation by a French car maker is to carburize this steel 0.005 to 0.010 in. deep, and harden by removing the gears from the carburizing box and cooling in air.

Rear axle pinion and ring gears are usually case hardened, although air hardened ring gears are used.

For rear axle shafts 3.0% nickel and the oil hardening chromium-nickel steels are common. For heavy duty work the air hardening steels are used. In large diameter shafts a steel containing 0.30% carbon, 4.00% nickel, 1.25% chromium, and 0.20% molybdenum, air hardened and tempered, gives a strength close to 200,000 lb. per sq.in.

BRITISH ENGINEERING STANDARDS ASSOCIATION SPECIFICATIONS

Number	Description	Chemical Analysis										Physical Properties						Heat Treatment	Typical Uses
		Carbon	Silicon, Max.	Manganese	Sulphur, Max.	Phosphorus, Max.	Nickel	Chromium	Vanadium, Max.	Molybdenum, Max.	Tungsten, Max.	Yield Point Lb. per Sq. In.	Ultimate Strength Lb. per Sq. In. Min.	Ultimate Strength Lb. per Sq. In. Max.	Min. Elongation Percent	Min. Reduction of Area Percent	Min. Izod Impact Ft.-lb.	Brinell Hardness		
3.S.15	3% nickel case hardening steel	0.10 to 0.15	0.30	0.20 to 0.60	0.05	0.05	2.75 to 3.5	Max. 0.30					100,000	135,000	18	45	40		Refine 1580°F. W.Q. 1420°F.	Valve rocker spindles, oil pump housing gear, magneto driving gear tappets.
D.T.D.3	5% nickel case hardening steel	0.10 to 0.15	0.30	Max. 0.40	0.04	0.04	4.75 to 5.5	Max. 0.30					155,000	190,000	15	40	30		O.Q. 1525°F. W.Q. 1385°F.	Gudgeon pins, crown wheels, bevel pinions, eccentric impeller gears
S.69	3½% nickel steel	0.35 to 0.45	0.30	0.50 to 0.80	0.05	0.05	3.25 to 3.75	Max. 0.30					125,000	145,000	18	50	35	241 to 293	O.Q. 1525°F. T. 935 to 1165°F.	Cam shaft gear, propeller hub crankcase bolts, clutch bolts.
3.S.11	125,000 lb. nickel chromium steel	0.25 to 0.35	0.30	0.45 to 0.70	0.05	0.05	3.0 to 3.75	0.50 to 1.0	0.25 Optional	0.65	1.0		125,000	145,000	18	50	40	241 to 293	O.Q. 1525°F. T. 1035 to 1225°F.	Crank shaft, impeller propeller hub bolts, valve washers, cylinder studs, cylinder head shrink band.
	Nickel chromium steel for crankshaft	0.25 to 0.35	0.30	0.45 to 0.70	0.05	0.05	3.0 to 3.75	0.50 to 1.0	0.25	0.65	1.0		135,000	155,000	18	50	40	269 to 321	O.Q. 1525°F. T. 1020 to 1115°F.	Crank shaft, rocker arms, gears.
2.S.28	Air hardening nickel chromium steel	0.25 to 0.32	0.30	0.35 to 0.60	0.05	0.05	3.75 to 4.5	1.0 to 1.5	0.25 Optional	0.65	1.0		225,000	–	12	25	15	Min 444	A.H. 1510°F. T. 480°F.	Crank shaft gears.
S.61	High chromium non-corroding steel	Max. 0.15	0.50				Max. 1.0	Min. 12.0					80,000	100,000	25	50	45	152 to 207	O.Q. 1725°F. T. 1115 to 1385°F.	Exhaust pipes, (less than 2 in. diam.)
S.65	150,000 lb. nickel chromium steel	0.22 to 0.28	0.30	0.35 to 0.65	0.05	0.05	2.75 to 3.5	1.0 to 1.4	0.25 Optional	0.65	1.0		145,000	155,000	17	40	35	293 to 321	O.Q. 1525°F. T. 935 to 1115°F.	Connecting rod, rocker arms.
D.T.D.43	Chromium nickel non-corrosive steel	Max. 0.20	0.60	Max. 0.60			6.0 to 10.0	16.0 to 20.0				50,000	110,000	–	25		40		Hard rolled	Exhaust port studs, (less than 2 in. diam.)
D.T.D.49A	High Nickel chromium steel for valves	Max. 0.55	3.0	Max. 1.5			Min. 9.0	Min. 12.0			0.0 to 6.0						15	207 to 293	O.Q. 1745°F. T. 1200 to 1300°F.	Valves
D.T.D.91A	110,000 lb. steel for tubes	Max. 0.50	0.30	1.5	0.05	0.05	Max. 3.75					100,000	110,000	Special flattening test (Note)					Cold drawn end blued	Tubes

Note: Flatten till sides of tube are separated by not more than 8 times thickness of wall or 7/8" bore whichever is the smaller

Acid-Resisting Metal Used For Pickler's Racks

By D. E. STAMM
and J. C. WEAVER
Weaver Bros. Co.
Cleveland

• • • PREVIOUS ARTICLES BY one of us dealing with pickling, which have appeared in METAL PROGRESS from time to time, have discussed the subject generally. This article will also refrain from specific details and definite recommendations as to the best method of doing certain things or the best material to use in individual applications. The subject of handling equipment is so wide it prohibits the making of definite recommendations unless definite data on the surrounding conditions are also available, since almost every plant has its own unique requirements. This article therefore will describe several styles of baskets and designs of carriers which may be made of different kinds of acid-resisting metal.

Once upon a time, pieces which were to be pickled were sprinkled with acid and scrubbed with brooms. It did not take a very ingenious man to find a better way than this; he built a tank for the double duty of holding the pickling solution and the work to be pickled. The process was simple. Forgings or other pieces were thrown into the tank, which was then filled with water and acid. After the scale was dissolved, the plug was pulled and the liquid drained. Perhaps the forgings were then sprayed with water to rinse them off, perhaps not; they were then taken out of the tank. No baskets or other handling devices were used.

It is quite obvious that such a procedure was expensive because some active acid was wasted, because much labor was consumed in handling the metal, and because uniform cleaning could not result from such a hit-or-miss plan. However, it was representative of ordinary conditions for several decades and is the big reason why pickling has always been considered such a dirty, messy, sloppy job.

An important innovation was the introduction of wooden trays or racks to carry the pieces to the acid, hold them while they were being pickled, and lift them from the acid tank to wash tank, and on out to the next department. These archaic wooden baskets have stayed in the pickle room much longer than any other class of ancient machinery has survived in the rest of the manufacturing plant. Picklers still use them because they believe the original cost is quite low, and even though they last for only two to four weeks, they are therefore cheap. Such reasoning is entirely erroneous.

If the labor of making the baskets is figured and to this is added the cost of the wood, the copper nails or other acid-resisting bolts, tie-rods, and pieces which hold the trays together, a surprising figure will result. An instance can be drawn from a forge plant, very modern in every department except in the pickling house, where wooden baskets had always been used. The pieces to be handled were very heavy, and since the forgings were thrown into the baskets, these lasted only a week. A year's supply cost

$5300. For an investment of $1600 the company secured a supply of acid-resisting baskets which lasted well over a year, and made a saving of at least $3700. While this is an extreme case, and it is doubtful whether everyone using wooden baskets can save 200% a year by buying metal pickling baskets, we are quite sure that the savings will indeed be notable if the proper type of handling device is used.

There are other items which prove that wooden baskets are not worth their salt. They are bulky and cumbersome. They take up more room in the pickling tank than they should and thus cut down the pay load. It is impossible to make wooden baskets with open slats, since any openings cut down on the much needed strength. Last but not least, wooden trays are treacherous because the strength of the wood fiber is gradually destroyed by the acid and no one can tell when the life of the basket is gone and just when an accident is apt to occur. A safety department should not tolerate the possibility that a basket might come apart while suspending a load above an acid solution.

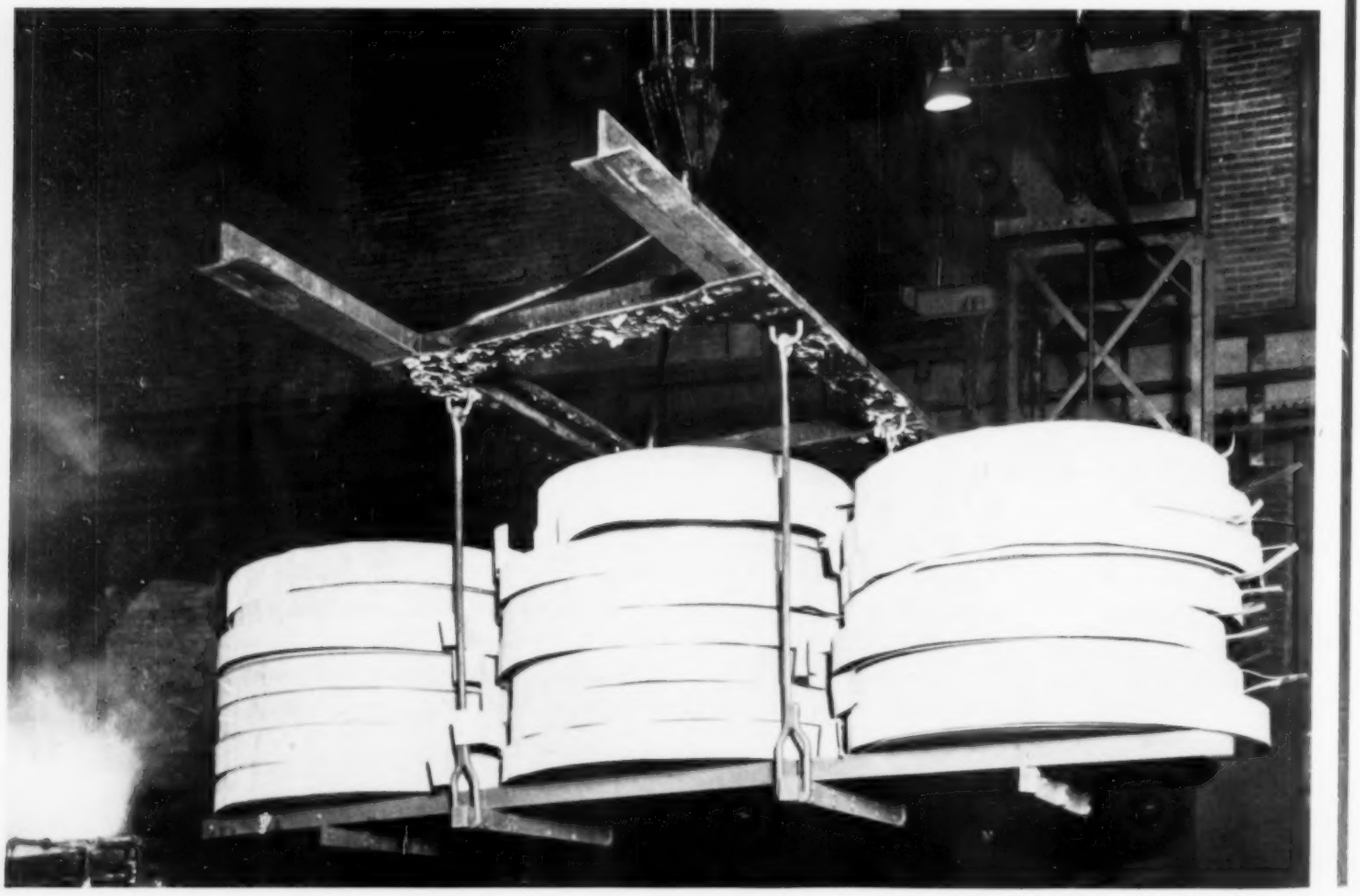
With the advent of such a variety of acid-resisting metals, there is small excuse for retaining wooden trays and they are rapidly being replaced by containers made of fabricated rolled metal or cast metal. Whether they be of riveted, welded, or cast construction, they are in every way superior to wood. They can be made of much lighter sections, which permit more open work with an ample margin of safety. They also last far longer.

Different plant conditions, which include the general design of the pickling department and the nature of the material being pickled, will dictate the type of basket to be used. Steel mills, which pickle sheet and strip steel, require very stout and stiff baskets or carriers. A figure shows a monel metal crate used for such purposes in first class condition after six years' service. Monel or cast bronze chain slings are most generally used to pickle bars, pipe, or seamless tubing.

Drop Bottom Baskets

If moderate-sized drop forgings are being cleaned, it can be done in several more or less standard designs of crates fabricated of bars and small structural shapes. A new type of basket has recently been designed by a progressive drop forge plant, incorporating a drop

Monel Metal Crate Used Six Years in Pickling Department of Strip Mill



bottom for quick unloading. Unloading a basket has been more or less laborious, but the basket shown in the figure works very well and is excellent for pickling small forgings.

Another company which pickles brake drums after they have been stamped and annealed, finds that a crate such as is shown in another figure serves the purpose extremely well. It was designed so the pieces could be kept separate from each other, yet may easily be loaded and unloaded. Of course, this general design could be used with little modification wherever a large number of similar pieces of moderate size are being treated. In all such baskets, particular attention should be given to the necessity that the solution should come in intimate contact with all pieces, so the metal at the end may be absolutely clean, without any unpickled portions remaining.

This aim is achieved when handling small or cup-shaped forgings by building a reinforced wire basket with a cover which can be latched down and the whole basket can then be rotated on side trunnions so the acid solution will be able to reach indentations quickly and easily. Baskets which are to hold small, comparatively light pieces must have wire mesh sides, or the slats fairly close together. Particular emphasis should be placed on the method of emptying these baskets. If the container is hung from a bail like a bucket, it can easily be dumped. Sliding end-gates or drop bottoms are also useful.

Baskets such as are used to a very great extent in the porcelain enameling field are very satisfactory for light steel pieces or light stamp sections. A series of T-bars with serrated upstanding legs forms the bottom of such a basket, and each piece is set over or between the teeth of these "combs."

Another handling problem presents itself in the wire industry. Coils of wire rod are heavy — up to 200 lb. — and if stacked flat the strands pack tightly and exclude acid from some of the turns. Yokes or "hairpin hooks" have therefore been largely used; coils are hung over them and the rods dangle more or less freely. Such hooks are usually made of a cast bronze, because that metal is much cheaper than a forging made of acid-resisting chromium-nickel alloys.

All the handling devices spoken of and shown in the pictures are heavy enough when loaded to require cranes, hoists, or some mechanical lift. Of course, there are some operations on small parts or of small volume which can be done by hand. Common wire mesh baskets, reinforced with heavy rod at top and bottom edges, and with upstanding handles at the end, serve very well.

Basket of Modern Design. Made of corrosion-resistant metal, open for free acid circulation. Has drop bottom for quick unloading

Cast bronze or rolled monel metal are the only two metals mentioned so far, but those are not the only ones which are used in the pickling department. There are several trade-marked bronzes on the market today and each has its particular points of superiority. Monel metal is one of the first metals to be used for acid resist-

ing work in the form of rolled bars, rods, and plate. It is an alloy well known to picklers, and has given an excellent account of itself.

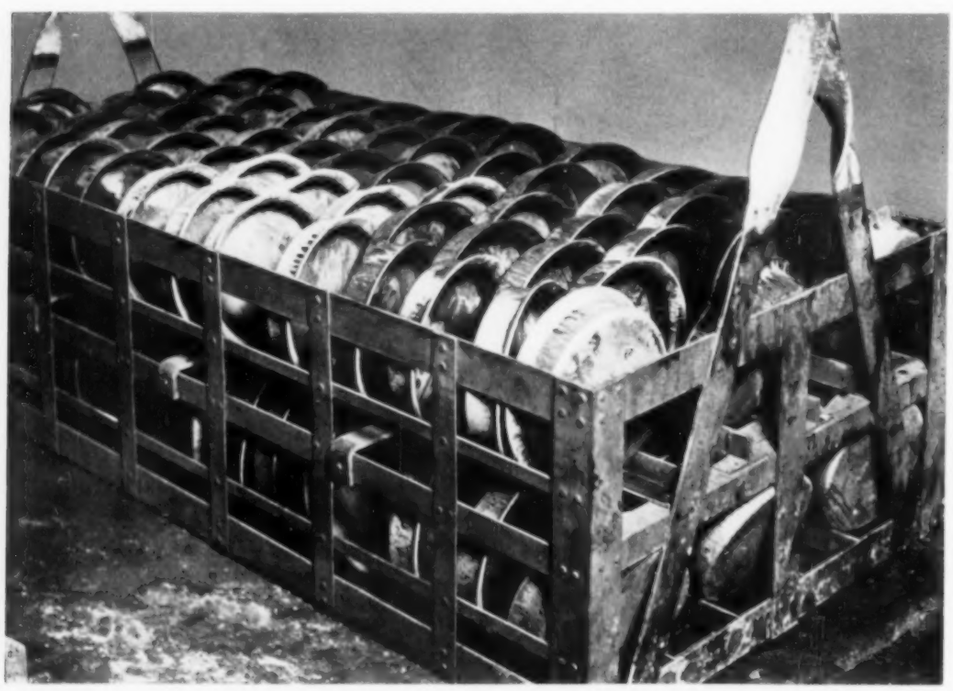
Within the last few years, various acid-resisting ferrous alloys have come to the front; all of them have a high percentage of chromium and some have a high precentage of both chromium and nickel. Chromium alloys are used quite successfully with nitric acid. "Duraloy" (high chromium-iron) was one of the first of these new alloys to be so applied. "Durimet" (a chromium-nickel-silicon alloy) has been used with success in straight sulphuric acid. This combination makes one of the few ferrous alloys which will stand up under such conditions.

Copper has long been used for pickling in sulphuric, but it is not a very strong metal; a little copper may also enter the solution and sometimes it plates on the work. Frequently, this copper plate is objectionable. Naturally, the life of copper equipment will not be as great as some of the stronger and stiffer metals mentioned above.

Sometimes mixtures of muriatic acid and nitric acid are necessary for pickling. "Nichrome" (nickel 60%, iron 25%, chromium 15% approximately) is undoubtedly the most satisfactory alloy for use in such solutions. It is not widely used because of its high price, but as an acid-resisting metal it is one of the best.

Rather recently, it has been possible to deposit rubber on steel so it will adhere strongly, and this gives a basket with the stiffness of iron and with a protecting cover of rubber. Such a basket should find use in muriatic pickling, as muriatic or hydrochloric acid seems to be the most corrosive on any of the above-mentioned metals. It is to be understood that while the life of the acid-resisting metal would be much longer than steel in such a solution, its life is not as great as it would be in sulphuric acid. Recently, an alloy of iron, nickel, and molybdenum called "hastelloy" has been described as resisting dilute hydrochloric acid indefinitely.

Racks or baskets made of an acid-resisting bronze are cheaper than those made of rolled monel metal or rolled durimet, yet the first-mentioned has a shorter life. The strength of rolled metal is usually much greater than that of the cast metal, and consequently lighter pieces of bar or rod can be used without sacrificing strength. This means that less metal is used and consequently the cost of the basket is reduced. So it is not hard to understand why some companies swear by cast bronze baskets and others by rolled monel baskets.



Pieces Which Have a Tendency to Nest or Which Have Cup-Shaped Depressions Should Be Racked, Held by Comb-Teeth, or Tumbled During Pickling, to Be Sure That Acid Reaches Freely All Parts of the Surface

3 more ways of reducing cost factors by using the strong alloys of Alcoa Aluminum

These are cost-reducing days—days when speed, accuracy and power-economy are writing success on cost sheets—days when surplus dead-weight and needless upkeep are banned by industry. These are days for the strong alloys of Alcoa Aluminum!

Ease of handling, for instance, is evident in the regulation-size skid platform shown here. It weighs only 65 lbs. yet supports a load of over 8200 lbs.

Lower repair costs will pay dividends to the owner of the motor-driven pump (*above*). It is made of Alcoa Aluminum which does not rust. And think of operating expenses saved by the 1900 lb. mine cars of Alcoa Aluminum whose steel duplicates weigh 3000 lbs!

Before you design a new product or redesign an old one consider the advantages of Alcoa Aluminum. Parts made of Alcoa Aluminum and its light, strong alloys can readily be forged, cast, welded, joined, machined and finished. Cost is low, on a par with other metals not having qualifications of Alcoa Aluminum.

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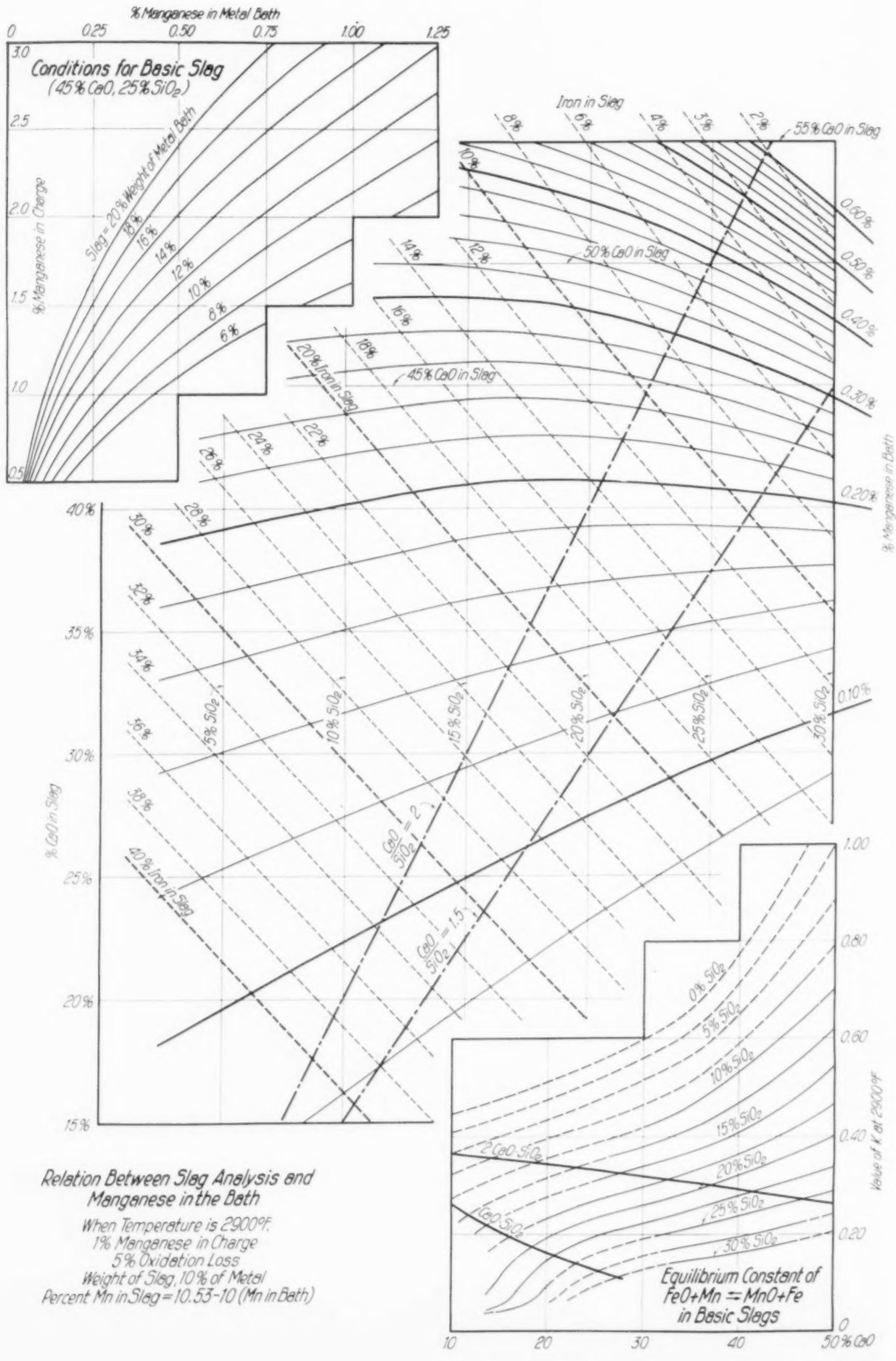

Relation Between Slag Analysis and Manganese in the Bath

When Temperature is 2900°F.
1% Manganese in Charge
5% Oxidation Loss
Weight of Slag, 10% of Metal
Percent Mn in Slag = 10.53 - 10 (Mn in Bath)

Correspondence and Foreign Letters

FREIBERG, GERMANY — More and more the importance of the melting procedure with respect to the quality of the finished steel has been recognized in recent years. Especially since 1926, after the joint session of the Faraday Society and the British Iron & Steel Institute relative to the physical chemistry of steel production, an attempt has been made to discover how far the reactions between steel and slag in the open-hearth process follow the quantitative laws of chemistry. These investigations have centered in the United States, on account of the comprehensive work of C. H. Herty, Jr., and his co-workers, but recently these questions have also been widely discussed in Germany.

Partition of Manganese — Slag to Steel

Particularly notable is the work of Oberhoffer, who attempted to solve the problems relative to deoxidation of the bath and of a correct method for determining oxygen. A paper entitled "Zur physikalischen Chemie der Manganreaktion, ihre Beeinflussung durch Bad und Schlacke" (On the Physical Chemistry of the Manganese Reaction — Its Influence on Bath and Slag) was later published by the undersigned. This paper, which discussed the fundamental influences of the different slag components, was supplemented by "Zur Frage der Manganreduktion bei der Stahlherstellung" (Reduction of Manganese During Steel Production) in which the deduced physico-chemical relationships are set forth in their commercial applications.

In order to determine the equilibrium of the reaction which is most important metallurgically, that is,

$$FeO + Mn \rightleftarrows MnO + Fe$$

a large number of slag analyses were obtained from the literature as well as a great number of our own (taken simultaneously with steel samples). These were then evaluated according to various viewpoints, and it was possible to deduce the equilibrium constant K of the equation

$$K = \frac{Mn_{(Metal)} \cdot Fe_{(Slag)}}{Mn_{(Slag)}}$$

as it varies with the silica and lime content of the slags ordinarily met in the acid or basic open-hearth process. These mutual relationships for basic slags at 2900° F. are shown in the curves at the lower right-hand corner of the data sheet opposite.

The influence of other components of the slag upon the constant K was interesting. Only when MgO exceeded 10% was it displaced toward lower values. Al_2O_3 showed a comparatively slight influence and displaced K toward higher values when the slag contained little SiO_2, and to lower values when the slag contained much SiO_2. P_2O_5, practically without influence up to a content of 3%, displaced K markedly toward lower values when the slag contained more than 3%.

Manganese, among the components of the metal bath, showed no influence on K up to 3.5%. (Our studies established the validity of the ideal law of mass action within this range for the first time.) Neither could we discover any influence of carbon up to 4%. On the other hand, increasing contents of silicon and phosphorus resulted in a considerable increase of the value of K.

A marked increase of K with rising temperature was calculated for pure slags, consisting only of FeO and MnO. The manganese reaction

Correspondence and Foreign Letters

in slags high in CaO and SiO_2 is less sensitive to temperature, as judged from plant analyses. In the presence of acid slags of more than 50% SiO_2, K decreased with rising temperature.

Inasmuch as a knowledge of the equilibrium constant does not establish directly the distribution of manganese between metal and slag, we further investigated the influence of operative conditions, such as the manganese content of the charge, volume of slag, and oxidation loss. This resulted in the following relation for the manganese content of the metal, which is independent of the total weight of the charge:

$$Mn^2 + \left(K - \frac{a}{D} + \frac{b \cdot R}{100}\right) Mn = \frac{K \cdot a}{D}$$

In the above equation, *Mn* represents the manganese content in the metal bath in per cent,

K is the equilibrium constant corresponding to silica and lime analysis of the slag (lower right-hand diagram, page 66),

a is the manganese content in the charge in per cent,

b is the amount of the slag at the moment, in per cent of the weight of the metal bath,

R is the sum of the per cent iron and the per cent manganese in the slag,

D is (100 — *d*) ÷ 100, where

d is the oxidation loss in per cent of metal charged.

According to the above equation, the slag composition, manganese in the charge, and the slag volume are of considerable influence on the manganese content of the metal bath; the influence of temperature (within operating limits) is very slight, as was shown by further calculations.

Curves on page 66 show how this equation may be plotted for practical use, when making certain assumptions chosen to represent average conditions for given operations. For instance, the family of curves at the upper left shows the relation between the amount of slag, the manganese in the charge, and the manganese in the bath when the slag contains approximately 45% CaO and 25% SiO_2, the oxidation loss has been 5%, and the temperature is about 2900° F.

The curves in the center of page 66 show the relation between slag analysis and manganese content of the bath for the following assumed conditions: 1% manganese in the charge, oxidation loss 5%, and weight of slag 10% that of the metal. Under these circumstances, the percentage of manganese in the slag will be 10.53 minus 10 times the percentage of manganese in the bath.

Obviously, the open-hearth metallurgist can compute and plot similar curves for ready reference for any other set of conditions prevailing in his furnaces.

The requirements for the reduction of manganese (which is considered advantageous metallurgically as well as with respect to plant economy) should now be completely clarified. The correlation between the course of the reaction, the composition of the slag, and the quality of the molten steel is a matter for future investigation. In fact, decisive relationships of this kind were determined, at least qualitatively, by an investigation of twelve charges for tube stock described in the first-named paper.

ED. MAURER
W. BISCHOF

Savings Due to Electrodes of Natural Graphite

TURIN, ITALY — Properties of electrodes of natural graphite, now being manufactured in Italy in large tonnages for steel furnaces, are somewhat different from those of the artificially graphitized electrodes used in other countries by the great majority of metallurgists.

It will therefore be interesting to give some information concerning the properties of natural graphite electrodes, since such facts will determine the technical and economic advantages when the selling prices of the different types of electrodes are taken into account.

Electrical properties — Resistance per meter on one square millimeter section does not exceed 10 ohms. Current density used with these electrodes runs normally between 16 and 18 amp. per sq.cm., which is amply sufficient for the furnaces used at present. Higher current densities can be used.

Combustibility is practically the same as that of graphitized electrodes. The oxidation temperature in air is about 850° F.

Mechanical properties — Resistance to bending is between 1500 and 1650 lb. per sq.in. of cross-section; for graphitized electrodes this varies between 1000 and 2400 lb. per sq.in. The hardness of natural graphite electrodes is slightly lower than that of graphitized electrodes. While this difference does not affect the behavior in any way when in operation in the furnace, it might cause some trouble when connecting two electrodes. During this process, the friction on the screws produces a small quantity of powder which might interfere with a perfect connection; any inconvenience in this respect can easily be avoided by carefully cleaning the screws with a jet of compressed air.

Behavior in the furnace — All other conditions being the same, the consumption of natural graphite electrodes is about 20% more than that of graphitized electrodes. This figure is based on a wide experience, extending over many years and with many types of furnaces. The excess loss arises partly from a slight excess of combustion and partly from breakages, due to insufficient attention given to the proper treatment of connecting screws.

Excepting for this higher consumption, the Italian electrodes have always given results as good and as regular as those obtained with imported graphitized electrodes. Under these conditions, it is evident that the convenience of using them depends principally upon the price.

Now, although the cost of the raw materials (natural graphite) used for these electrodes is higher than that of materials (anthracite or petroleum coke) used for the manufacture of graphitized electrodes, yet the final manufacturing cost of the former is 35 to 40% less. This great difference is due chiefly to the fact that the manufacturing process does not include the expensive operation of graphitization. The lower price means a final saving of 15 to 20%, even when the higher rate of consumption is taken into account.

Another important advantage of the natural graphite electrodes, especially for the modern steel furnaces of very large sizes, lies in the fact that these electrodes can easily be manufactured up to very large diameters (20 to 24 in.) without increasing their cost per ton, and without the slightest change in their good qualities.

FEDERICO GIOLITTI

Correspondence and Foreign Letters

Impurities in Metals, Known & Unsuspected

PARIS, FRANCE — Impurities in metals in very small quantities have been found by more and more searching and precise methods of chemical analysis. Preparation of samples of purer and purer metals has indicated the influence of very small quantities of elements whose presence was formerly unknown or whose influence was overlooked while attention was centered on some others, better known. This observation may be paralleled in the world of medicine: Physicians discover new diseases or new remedies in proportion to the amount of research or as its quality improves.

It is known, of course, that catalysers are "poisoned" (become ineffective to influence the desired chemical reactions) by infinitesimal doses. For example, HCN poisons platinum sponge if as much as 0.000 000 13% is present! Aside from these extreme examples, it is beyond doubt that very small quantities of impurities can exert a notable influence on some properties of metals. It can therefore be predicted that as the usual impurities are eliminated from com-

Correspondence and Foreign Letters

mercial metals, we will be able to modify profoundly some of the usual characteristics. As an example may be cited the influence of some gases, such as hydrogen and nitrogen, on the critical points of iron.

But it would be a great error to consider all "impurities" as detrimental, or as having an influence of similar importance. The effect is very variable; it depends upon the impurity, the metal, and the property under consideration.

Generally, the non-additive properties (that is, those which do not follow the rule of mixtures, such as electromotive force of solution, corrosion rate, electric conductivity, and conduction of heat) are the ones most sensible to the effect of impurities. However, a distinction must be made according to the state in which the impurities exist.

In the first place, if the "stranger" element is in solid solution in the metal, it will have the greater influence on electrical conductivity the farther it is removed on the periodic sequence. Bosshard used this general rule to determine the influence of unsuspected impurities, such as traces of titanium in aluminum. Vanadium also should be mentioned; its atomic volume and its position on the periodic table of elements are close to titanium. Amounts as low as 0.1% of either metal increase the resistivity of aluminum to 3.0 microhm per c.c. (Pure aluminum is 2.7.) This is most important in the manufacture of wire for electric lines.

Some elements in solid solution, principally the "anti-oxygens," can notably improve the resistance of steels to corrosion.

When refining or depositing metals electrolytically, small traces of elements in solution in the electrolyte impair the quality of the deposit and reduce the yield. As an example of such an unsuspected influence, Tainton and Clayton have found that 0.000 000 1% germanium can lower the current efficiency, when depositing electrolytic zinc.

On the other hand — when the impurity forms a component not in solid solution — it can have a notable effect on corrosion and mechanical properties, particularly on brittleness or malleability. It is enough to remind the reader of the influence of inclusions in steel, but it must not be forgotten that the intensity may depend to a considerable extent on the structural state — that is to say, on the form and the distribution of the inclusions.

For instance, sulphur lessens the malleability of iron or of nickel, because the sulphides or oxy-sulphides are distributed as thin, brittle films, but when manganese is added to iron or magnesium to nickel, the sulphides coalesce into tiny rounded shapes that permit these metals to be forged or rolled. Similarly, the oxides in tough pitch copper, which exist in the form of globules without causing damage, take the form of a network after remelting (as in welding some copper plates or bars) and thus cause the joints to be brittle and useless.

The conditions of fabrication may introduce inclusions, at first harmless, but in such amounts that suddenly there arise difficulties in manufacture without any apparent reason. In the foundry, remelting of sprues and risers increases the proportion of oxides in the metal when these cannot be removed by suitable fluxing or additions. This happens frequently from alumina and magnesia in the aluminum and the magnesium foundry; periodical defects may appear in such a way as to suggest an apparent instability in the process or product.

As is well known, important hardening effects can be attained by means of very small quantities of elements, by the transformation of the component into scattered particles of optimum fineness.

It would appear, therefore, that a thorough study and certainly a number of precise determinations are necessary before one can give an opinion as to the danger or harmlessness of impurities. Some which were at first considered as harmful ones turned out afterward to be useful.

For example, silicon, originally considered as a harmful impurity in aluminum, is, in fact, absolutely necessary for hardening the light alloys containing magnesium, because the essential compound is Mg_2Si. Copper was formerly banished from steel, now it is used in small quantities to improve the resistance to corrosion and in larger amounts to increase the strength.

Lastly, one may cite sulphur, considered as a harmful element in the manufacture of malleable cast iron, yet which must, on the contrary, be balanced against the manganese content to neutralize the effect of the latter, for they both separately offer resistance to graphitization, but jointly they form a sulphide which has no action. This explains the failures that occur in the manufacture of malleable by the duplex process when using a basic electric furnace which carries the desulphurization too far. An acid furnace should be adopted, which allows the melter to adjust the sulphur content to the manganese by means of proper slags.

The prime difference between metallurgy and chemistry may be stated thus: Metals, instead of being sold as chemical products and valued in proportion to their purity as determined by analysis, are sold according to their physical properties — which depend on many other factors than ultimate analysis.

ALBERT PORTEVIN

Correspondence and Foreign Letters

Speculations on Hardening by Electromagnets

LONDON, ENGLAND — Development of very hard materials (such as cutting tools consisting largely of tungsten carbide, or the nitrided surfaces of steel) has done much to raise our ideas of the degree of hardness which is attainable in industrial metals, and it is not unnatural that workers in steel, as distinct from tungsten carbide alloys, should endeavor to meet the competition of the new materials by seeking to produce superhardened steel.

Our understanding of the processes by which steel is hardened has been deepened by the exhaustive study which has in recent years been given to the age hardening processes in nonferrous alloys and also by the modern investigation of the structure and constitution of hardened steel by X-ray analysis. Quite recently, for example, X-ray methods have been used with considerable success to determine the proportion of residual austenite present in fully hardened steel. The results of this measurement serve to confirm the inference, which knowledge of the age hardening phenomena would justify, that steel — even when hardened as fully as possible by quenching — is not completely hardened in the sense that a considerable proportion of its mass still consists of ductile material whose inherent plasticity has not been completely destroyed.

In these circumstances it is not suprising that processes should have been discovered whereby hardened steel can be further hardened or superhardened. Some years ago Hultgren demonstrated the superhardening of fully hardened steel balls for ball bearings by subjecting them to severe cold working. More recently, E. G. Herbert in this country developed an ingenious method of superhardening which is now well known under the rather fanciful name of "cloud burst." The process, it will be remembered, consists in subjecting the surface of the material which is to be superhardened to bombardment by a large number of small, hardened steel balls falling from a height of from 3 to 10 ft. The surface hardening which can be produced in this way is considerable and is proving of practical importance for certain purposes. From the present point of view, however, more interest attaches to the subsequent developments.

It has long been known that freshly hardened steels and also freshly cold worked steels undergo spontaneous changes in hardness and other properties in the course of some hours.

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Some years ago Hadfield and Brush showed that hardened steel gives out a small amount of heat for a considerable time after hardening, while Muir, working during 1900 in the same research laboratory in Cambridge as the present writer, showed the series of changes undergone by freshly overstrained mild steel and the marked effect upon them of quite moderate temperatures such as boiling water.

After studying these phenomena Mr. Herbert put forward some startling observations according to which a very simple magnetic treatment, such as slowly turning a specimen of hardened steel through one revolution while lying across the poles of a powerful electromagnet, produces a series of marked changes in the hardness of the specimen. His curves show, in some instances, that the magnetic treatment first of all brings about an immediate reduction of hardness followed by a gradual rise and a series of further fluctuations. Repetition of the magnetic treatment reproduces these phenomena, although, apparently, not indefinitely since after a certain number of treatments a different series of changes sets in.

These observations, which Herbert has described in a number of papers, are of remarkable interest both from the scientific and the practical point of view. Their industrial importance lies in the fact that he claims to be able, by this very simple magnetic treatment, to increase the hardness of a hardened tool steel by a considerable amount and, further, to be able to stabilize the condition of the steel in that superhardened state. (From the scientific point of view it would be extremely interesting to know that a very simple magnetizing process is able to effect internal changes in the metal as considerable as the changes of hardness described.) There is also the further observation, published by Herbert, that similar although much less strongly marked changes of hardness can be produced by magnetic treatment in such substantially non-magnetic materials as duralumin and brass.

While the writer feels that this great mass of observations undoubtedly deserves very serious attention, he cannot deny that Herbert's claims for what is really a sensational discovery have so far been received in this country with a large degree of scepticism. There can be no doubt that when an investigator states that he has made so striking a discovery he should do everything to substantiate his facts. For that purpose it is not sufficient to rely only upon his own observations. So far we have heard nothing of any independent investigator having been able to reproduce the published results; in fact, in so far as the writer is aware of any attempts in that direction, they have not been successful.

Unfortunately, Herbert has put forward two theories to explain the phenomena which he has observed, not likely to secure serious attention from scientific metallurgists or physicists. His latest theory, which tries to explain what he calls the "periodic" changes of hardness by a precession of electrons around the atom of the magnetized material, has led him to infer that other properties besides hardness must be affected at the same time. Unfortunately, this constitutes no test of the theory because it is well known that hardness is in reality a function of a number of properties of the material and that these and others will vary more or less together.

It would be unfortunate, however, if sound observations of interesting facts were to be discredited because of unsatisfactory theories. In the writer's opinion, the facts put forward are at all events worthy of very careful consideration. One or two independent investigators could profitably take the matter up and either confirm or dispose of them finally.

WALTER ROSENHAIN

SENDAI, JAPAN — Yawata, a steel center, entertained the autumnal meeting of Japanese Iron & Steel Institute, last fall. Imperial Steel Works, the largest *(Continued on page 92)*

Immersion Melting With Gas

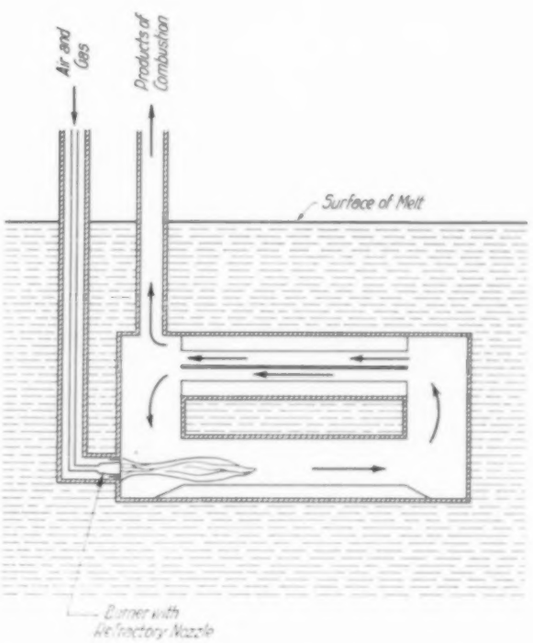
By E. B. DUNKAK
C. M. Kemp Mfg. Co.
Baltimore, Md.

. . . BY IMMERSION MELTING is meant the melting and heating of metals, salts, and liquids with heat from a unit placed inside the container. It is sharply distinguished from crucible melting or pot melting, where the heat is applied externally and driven through the walls of the container by conduction. Most barbers use a simple type of immersion heater to boil water for sterilizing the razor — it is a small electric resistor contained in a nickel plated tube. The present article will confine itself to gas-fired units of considerably larger size than this electric water heater.

Despite the obvious thermal economy in generating the heat where it is needed, the practical application of this general idea to the melting of metals did not occur until about 15 years ago. One prime reason for this was that alloys corrosion resistant at high temperatures had not yet been developed. Since that time, and as a result of continuous experimentation and investigation, the development has been satisfactory and at present it may confidently be stated that immersion melting can be used for almost any bath up to 1800° F.

The exceptions are specific applications; for instance, galvanizing, where no material is yet available for the heating unit which will successfully resist attack by zinc. Other soft metals are being so melted in large quantities, manufacturers and users realizing that immersion units can economically control rate of heating, top temperature, and dross formation. Instances are the melting of lead, for refining or for casting into billets or battery grids, melting of tin and lead for manufacture of tin and terne plate, the compounding of die casting alloys and of solders, the remelting of white metal scrap, and in equipment (such as for electrotyping and for automatic can making) which includes a pot of low melting point metal. In the heat treating field attractive results may be achieved in the heating of salt baths for hardening, annealing, or tempering, and in the heating of lead and oil baths for tempering.

Successful units, gas fired, all depend upon the immersion of a tubular heating surface be-



In an Immersion Heater a Gas Flame Is Blown Into a System of Welded Alloy Tubing. Part of the circulating products of combustion is continually removed through a chimney

At the Right of These Views Is a Large Lead Pot, Heated With Immersion Units. One picture shows molten lead being tapped out into one of five billet molds. After the metal solidifies it is hoisted out by a steel ring, frozen into the top surface

low the level of the bath. Details of such units, as installed in salt baths for the annealing of wire at 1650° F., are as follows:

Each heating element is fabricated from 5-in. diameter high nickel-chromium tubing welded in the form of a rectangle as shown in the accompanying drawing.

A single burner head discharges a pre-mixed and completely combustible air-gas mixture under pressure into the horizontal cross-over, and this high velocity flame entrains products of combustion from the upper cross-over. The admixture with these products of combustion reduces the flame temperature somewhat and the circulation produces a uniform temperature throughout the entire element. A portion of the waste gases is drawn off continuously through the vent pipe located just above the burner, while the balance again recirculates with the burning gas.

The burner head is also constructed of high nickel-chromium alloy in which has been set a replaceable refractory disk pierced with a large number of holes (No. 58 drill), each of which forms a burner port. A turn-down ratio of 100 to 1 facilitates automatic temperature control.

The number and size of heating elements applied to a given operation are determined from data and experimental information. In this way it is possible to predict in advance the thermal efficiency of the contemplated installation.

Assuming that such units are available in various sizes, fuel economies totaling 35% are possible from at least three different factors:

1. If a pot, externally fired, is used, the pot is ordinarily designed to hold the required amount of metal, irrespective of whether it has too much or too little external surface for the absorption of heat. Usually stack temperatures will increase when the unit is pressed for production. Immersion

heaters, on the other hand, are designed for heating and for nothing else, and can be installed with enough heating surface to melt a given amount of metal (or heat a given amount of cold metal entering the hot bath) with a predetermined efficiency.

2. There is a minimum barrier to heat transfer. Inasmuch as the externally fired pot must act as a supporting container, its wall thickness is sometimes as much as 20 times that of the walls of an immersion unit. Obviously, this opposes the transfer of heat and prevents rapid transmission of extra heat when extra heat is required.

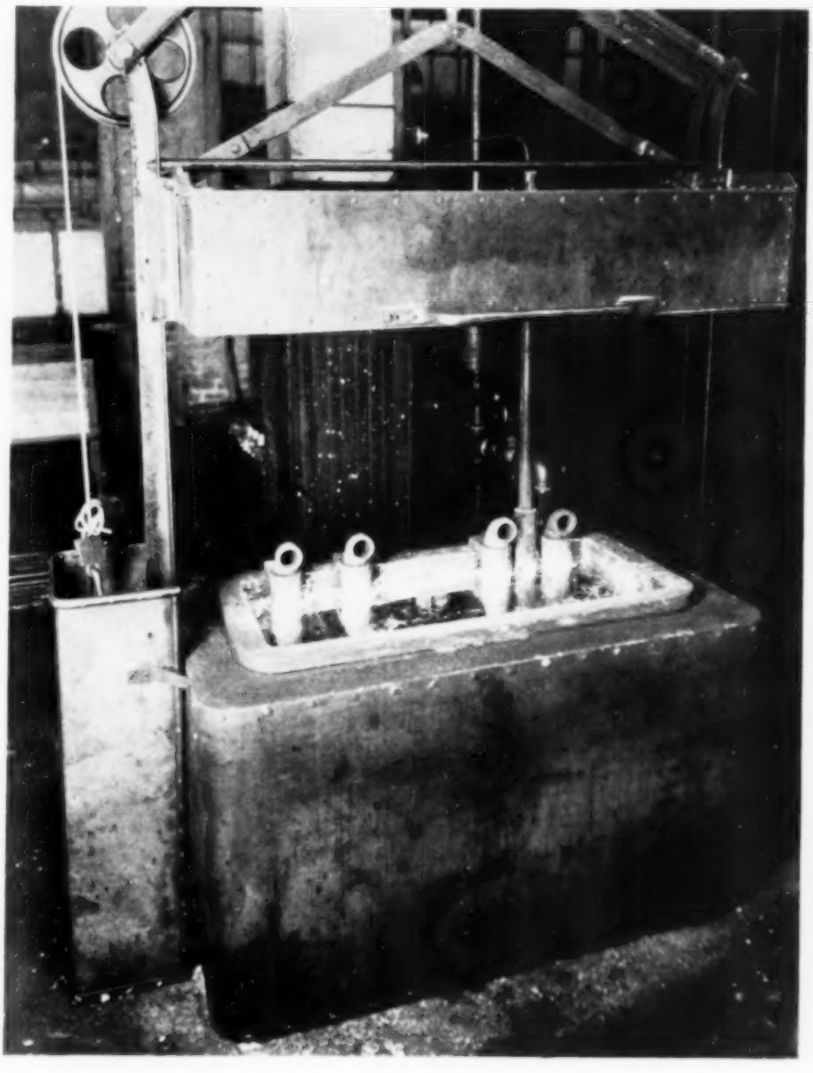
3. An important saving is possible by reducing radiation through the setting. In external practice highest temperatures exist in the combustion chamber surrounding the pot. This means that the container is hotter than its contents. In internal (immersion) practice, the container is set in a bed of insulation and its temperature can never exceed the temperature of the contents.

It is apparent from this that immediate economies are assured from the reduction of radiation losses. Also there is a very important economy effected when the pot is operated at low load or when the contents are at the predetermined temperature and the firing equipment is turned down to low load. Under these conditions, with external practice, air currents filtering into the combustion chamber extract heat from both brickwork and container. With immersion practice this condition cannot exist (since the outside combustion chamber is entirely eliminated) and a positive pressure may be maintained in the interior of the heating elements themselves at all rates of gas flow.

A point, related to the above, worthy of mention is the speed with which a bath or pot can be brought to temperature. Since there is no barrier to heat flow — little to absorb heat save the material to be heated — large baths can be brought into service in a very short time. For example, the temperature of a 20-ton lead pot, out of service for 48 hr., can be brought to 700° F. in 2 hr.

Important though the matter of fuel econ-

Immersion Melters in a Die Caster's Remelt Pot. Adequate insulation keeps heat losses to a very low figure



omy is, there are certain operations where precise temperature control is more essential — such as the tempering of oil-quenched wire. Probably all readers of METAL PROGRESS will accept the dictum that there is more to the control of temperature than the installation of an accurate controlling pyrometer. Such an instrument, for instance, cannot prevent overheating of a tempering bath if the burners cannot be turned down low enough when there is no work going through.

About 15 years of experience has indicated that equipment heated with immersion units may be more easily and precisely controlled. The reasons are as follows:

In the first place, there is no mass of hot brickwork in the combustion chamber to complicate matters. This might be thought of as a "fly-wheel," a mass of stored energy available for sudden demand, but in practice it does not work out so advantageously. Firing may cease entirely, due to lack of demand or an excessive bath temperature, yet heat will still continue to flow from the combustion chamber lining, which necessarily must be hotter than the inside of the bath. This causes an unavoidable over-run in temperature. Conversely, when the temperature in the bath must be boosted, and the burner again starts functioning, there is a delay caused by the absorption of a considerable portion of the heat by the firebrick setting.

A definite example will show how little heat is stored in the corresponding portions of an immersion heater. A 20-ton lead melting pot is heated by elements weighing only 800 lb. At maximum rates of heating the flue gases are only 105° F. hotter than the lead. On the reasonable assumption that this represents the average difference in temperature between heating element and material heated (under the worst condition), it can be computed that after the control valves close the 800 lb. of heating elements can only give up to the molten lead a total of about 13,000 B.t.u. This would heat 20 tons of lead 7° F., if the transfer could be made instantaneously. As a matter of fact, the transfer is slower than the lead pot loses heat to its setting and to the air by radiation, so a slight amount of gas must always be burned to maintain temperature in an idling pot.

Absence of large bodies of stored heat in settings thus eliminates the "fly-wheel" effect, prevents over-run of temperature, and enables the controlling equipment to put heat into the pot much more quickly. This obviously simplifies the control and enables the operator to hold the heat within narrower limits.

Heat distribution through the liquid is also more uniform. With external firing, all the heat is applied around the sides and at the bottom, thus naturally producing higher temperatures at these surfaces. In immersion melting the elements may be distributed throughout the entire pot with a consequent uniformity of temperatures throughout the metal mass. This is of major importance in baths that are used for heat treating, and it always has a pronounced effect on dross formation, as will be shown.

Another factor which is evident on cursory examination is the improved life of the container pots or tanks, even though they may be made with considerably thinner wall. The outer surface of the pot is not struck by flames, nor is there any chance for local overheating — the prime cause of most container failures. Neither can the inside surface ever become hotter than the liquid it contains, even locally; hence any corrosive or alloying actions are kept at the minimum. With these two considerations in mind, and also knowing that the entire container will be bedded down in an insulated setting, which itself can be stayed to resist hydrostatic forces, the designer will be justified in making the pot or tank of minimum thickness for stability, and need not avoid lapped seams if such are convenient.

Of course, the metal tubing in the immersion element is subject to some of the conditions that lead to quick failure in externally fired pots. These are minimized by proper design, as, for instance, by installing enough of them so that none run very hot even at maximum output. Furthermore, each element is light and relatively inexpensive, and can easily be replaced after eventual failure.

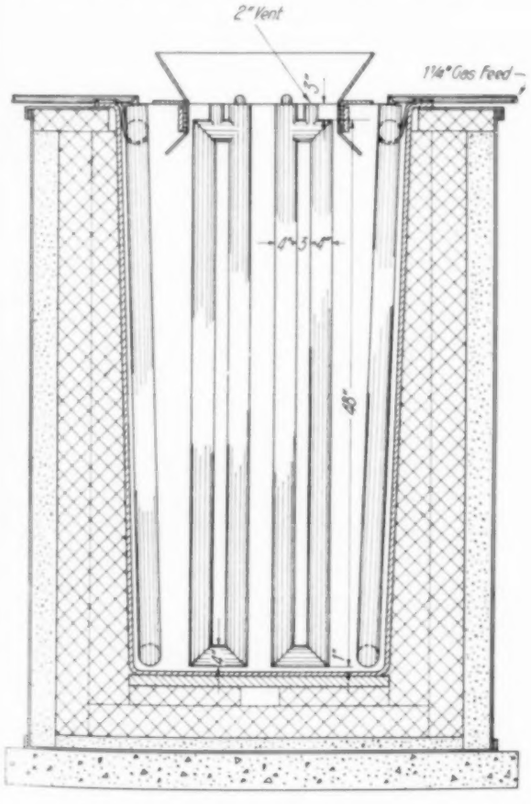
A minor matter to heat treaters using small metal baths is the formation of dross on the surface; however, losses through oxidation mount larger in plants making or using the white metals and their alloys.

Drossing is a chemical action, principally due to slow oxidation of the metal at the sur-

face. It is always bad on a pot which is overheated, either generally or locally, and by its very nature is a continuous reaction and can be reduced only by keeping the metal at the minimum temperature and protecting its surface from the air. Enough has already been said to indicate that an adequate number of immersion units under proper control will keep the heat under close control. The design can also be arranged so that the products of combustion, instead of being piped to a chimney, can be discharged at the surface of the melt, play over it, and be drawn out a hood, thus blanketing off the normal atmosphere with an artificial one containing little free oxygen.

It might also be mentioned that the improved metallurgical results are also associated with improved working conditions — although that is such a common observation in many other lines of activity that it would almost be taken for granted. Workshop or foundry surroundings are improved because the melting units are better designed and operate at lower temperatures without any exposed flames and roaring noises. Complete control of the gas and air mixtures and pressures at the various burners also prevents the formation of any carbon monoxide or other noxious products of combustion.

Cross-Section of 4-Ft. Salt Pot for Annealing Equipped With Six Immersion Heaters, for a Wire Mill in Pittsburgh District



Illustrations are taken from a recent installation where lead scrap is being continuously remelted for the casting of billets. These billets are later placed in an extrusion press for the coating of rubber hose prior to vulcanizing. Operating temperature is 740° F. plus or minus 5°.

Prior to this installation two pots were used, both heated electrically. Considerable trouble was encountered with excessive dross and litharge formation, a condition which the new installation has largely overcome.

The five billet molds shown in the illustration are filled every 40 min., each resultant billet weighing 1340 lb. Recently tabulated performance data indicate a thermal efficiency of 52% with lead being melted at the rate of 8.7 lb. per cu.ft. of 530-B.t.u. gas.

A second interesting application is in a tin plate mill in the Pittsburgh district, for heating the tin pots wherein the steel sheet is coated. It is obvious that here the immersion units may be placed so they will liberate the heat where it is most needed, namely, near the line where the cold steel dips into the hot metal. Economies have been made in the first cost of the rather intricate container, since it can now be made of welded steel plate of moderate thickness. Data on performance, as compared with the older pots, externally fired, are as follows:

Previous fuel consumption, 42 cu.ft. per base box of product, has been cut to 23 cu.ft., a saving of 45% in fuel.

Previous range of temperature — plus or minus 15° — may be contrasted with a present range of plus or minus 2.5° F.

A very important item in heating operations involving tin is the matter of dross formation. Previously, 1.85 lb. was produced per hr., whereas with internal heating, but 0.47 lb. is produced — a reduction in dross of 75%.

In addition to all the foregoing advantages, production has actually been stepped up from 260 boxes per day of 8 hr. to 300 boxes, an increase of 15.4%.

Concentrates from current literature

LAST SUMMER a series of 27 papers on the effect of temperature on the properties of metals was presented to a joint meeting in Chicago of the American Society for Testing Materials and the American Society of Mechanical Engineers. These papers, totaling 560 printed pages, together with 170 pages of discussion and comment and about 100 pages of bibliography and index, are now issued in a bound volume at $6.00 by the first-mentioned society. It is impossible here to do more than mention the fact that this encyclopaedic volume summarizes the state of knowledge as of 1931 as to the engineering requirements and the suitability of special metals and alloys to meet **HIGH TEMPERATURE SERVICE.** That such a compendium is necessary may be gathered from the fact that the alloys believed to be most suitable in 1921, as described in a symposium then held by the same groups, have not survived. Further evidence of the rapid advance in this field of metallurgy is the fact that various authors in the book being reviewed discussed the serious problem of intergranular corrosion (embrittlement) without suggesting any remedy other than the palliative of re-heat treatment before corrosion made much headway. In the last year the problem has been solved, as was disclosed at the February meeting of the American Institute of Mining and Metallurgical Engineers.

A PLEA for more intelligent handling of hot ingots between mold and rolling mill is made by an anonymous practitioner in *The Iron Age* for January 28. Most superintendents have fixed upon **MINIMUM TIMES IN THE SOAKING PITS** for ingots charged hot and for ingots charged cold — two complete schedules for the various sizes being cast. Unless the mill produces high carbon or alloy steel or ingot iron, this schedule will seldom make an allowance for chemical composition of the steel, its surface condition, or internal soundness. Yet it is well known that screw steel and the 0.20% carbon forging steels are prone to crack during rolling unless the temperature is correctly adjusted to the other variables in composition, structure, and pouring practice.

AN ARTICLE by H. R Houchins and C. McMullen in January *Metals and Alloys* points out that silicon carbide makes excellent muffles, furnace floors, and floor supports because of its high heat conductivity (which promotes temperature uniformity and fuel economy) and its great refractoriness and high strength (which lessen movement under load and prevent sticking to the work, thus reducing the repair bill). It must, however, be protected from iron oxide. Since it is "non-spalling," cold metal can be charged on hot hearths with impunity; successful **RECUPERATORS MADE OF SILICON CARBIDE** tubes are also due partly to this property. In the form of a plastic it is used for rammed furnace linings, especially for rolling or tilting electric furnaces in the brass industry, and is very resistant to mechanical and flame abrasion. No less important is the electrical conductivity of the carbide, which fits it for high temperature resistors ("globars") for heating electric furnaces to heats which would melt any common metallic alloy resistor and in atmospheres which would rapidly oxidize carbon electrodes.

A STUDY of the iron-manganese-carbon ternary equilibrium by the United States Steel Corp. research laboratory furnished raw material for a brilliant Howe lecture "On the **RATES OF METALLURGICAL REACTIONS** in Solid Steel" by E. C. Bain *(Continued on page 80)*

PRICELESS

are the voices of those we love

WHAT PRICE COULD BE SET ON THE VOICE AND LAUGHTER OF A LITTLE CHILD A THOUSAND MILES AWAY? WHAT PRICE ON THE BRIEF AND REASSURING PHRASE, "WE'RE ALL WELL"? WHAT PRICE ON A HUNDRED WORDS BETWEEN SEPARATED LOVERS?

What price on a doctor's midnight directions, on the swift response of the fire department, on the relief of anxiety, the cementing of friendship, the unexpected greeting after a long silence?

What price on speed in business, on the smooth running of a household, on leisure or rest without neglect of duty, on shelter in a day of storm?

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(Continued from p. 78) at the A.I.M.E. meeting February 18. Rates of change in the reaction

austenite ⇌ ferrite plus carbon

were measured in a series of steels ranging from fractional up to 13.5% manganese. It was shown that all the changes require measurable time to get under way, and that many appear to be entirely completed in finite time; with these two qualifications the middle of a typical time-transformation curve is closely approximated by a formula derived from the probability that the rate of reaction is inversely proportional to the amount of unstable phase remaining untransformed. Among the many interesting experiments described is the following: A 6½% manganese steel quenched in water is austenitic; further cooling in liquid air develops some clear broad martensite needles. If this sample be tempered at constant temperature, the white martensite needles decompose into ferrite and carbide, and the reaction is completed before any changes are observed in the austenite. The latter slowly changes into nodular areas of pearlite. From the observed fact that the rate of decomposition of martensite is so much faster than that of austenite, Dr. Bain concludes that martensite is not necessarily an intermediate step in the decomposition of austenite into pearlite. Of more immediate "practical" importance will be his curves showing the progress of tempering. Tempering is shown to be due to the diffusion of carbide occurring very rapidly at first, but continually tapering off in speed. Therefore, most of the softening of tool steel, for instance, is done in the first 20 min. at temperature, although the action is not entirely completed in many hours.

MACHINABILITY of common alloy steels after various heat treatments has been measured by T. G. Digges and reported in Machine Shop Practice Paper 54-4, American Society of Mechanical Engineers. He used the same blunt-nosed tool of high speed steel for a given finishing cut as utilized for similar work

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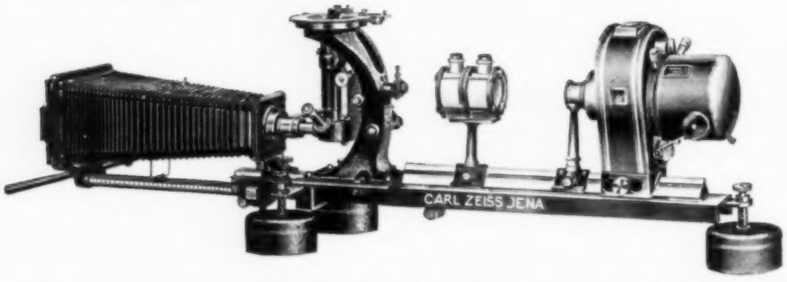

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at the Bureau of Standards, and **MACHINABILITY OF ALLOY STEEL** is reported in terms of cutting speed for breakdown in given time. S.A.E. 1040 is the least machinable at all tensile strengths from 120,000 to 80,000 lb. per sq.in., while chromium-vanadium (6140) is the most machinable at strengths from 160,000 down to 120,000 lb. per sq.in. Tools working on S.A.E. 6140, 4140, 3140, and 2340 all had a Taylor speed between 300 and 320 when the forgings were heat treated to the range 90,000 to 100,000 lb. per sq.in. tensile strength. Similarly tools have a Taylor speed of about 150 ft. per min. when working on S.A.E. 3435, 3140, 4140, and 2340 heat treated to 160,000 lb. per sq.in. At the high strengths of 210,000 lb. per sq.in., corresponding to hardnesses in the non-machinable range, as ordinarily conceived, S.A.E. 3435 and 3140 gave about the same Taylor speed (105) whereas S.A.E. 4140 permitted only 60 ft. per min. High cobalt high speed tools permitted 20% greater Taylor speeds on S.A.E. 3435 heat treated to strengths between 140,000 and 180,000 lb. per sq.in.; when the test log was harder or softer this advantage was not nearly so great.

FOUR theories of the lamellar structure of pearlite are (1) that ferrite etches more rapidly than cementite which stands out in relief and casts shadows on the ferrite ground, (2) that this relief is due to a difference in hardness with consequent difference in wear during polishing, (3) that ferrite is tarnished so as to appear dark, and (4) that a galvanic action in etching causes the boundaries between the constituents to be attacked and appear dark. M. Mikami, in *Science Reports* of the Tohoku Imperial University for December, attributes the **MICROSTRUCTURE OF PEARLITE** to the difference in both solubility and hardness, since he found that samples polished only on parchment paper and not etched showed the characteristic structure. When polished on emery the valleys are probably filled with a fine powder which is dissolved out on etching. Since the ratio of thickness of ferrite and cementite layers

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is about 6 to 1, and since the white area of pearlite is approximately equal to the dark area, it is evident that the shading is not due to surface coloring of the two constituents but rather to the reflection of light. After experimenting with photographs of a model constructed to have the 6 to 1 ratio, the author concluded that with vertical illumination the tops of lamellar cementite appear white and side faces dark, whereas the bottoms of ferrite valleys appear white and the edges dark.

ATTAINMENT of a degree of accuracy in forgings which will eliminate expensive machining operations has always been limited by the lack of sufficiently precise equipment. By means of a recently developed machine, however, hammer or machine forgings can now be finished by pressure with such precision that rough machining and in some instances even finish machining may be omitted. Some of the results obtained with this machine, known as the Maxipres, are described by John H. Friedman in the S.A.E. *Journal* for February. Where parts must be finish machined after **PRESSURE MACHINING**, the uniformity gained in the latter process is a distinct advantage in fitting the parts into jigs, fixtures, and other devices. The work may be done directly after forging without reheating, or on the annealing heat. In either alternative the temperature is below that for scale formation, and a fine finish results. Cold coining and complete forging on the Maxipres are possible but the latter is successful only for certain types of parts. The process is also applicable to forgings of brass and to straightening and sizing malleable castings to a uniformly close tolerance.

ONE session at the annual meeting of the Society of Automotive Engineers in Detroit, Jan. 25 to 29, was devoted to **BEARINGS**. D. E. Anderson, Bohn Aluminum & Brass Corp., in presenting the manufacturer's viewpoint, described a new type of bearing for automobile crankshafts. The total thickness of this bearing

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is only 0.050 to 0.100 in., of which 0.015 to 0.020 in. is babbitt, the rest being a steel back for strength. Alex Taub, research engineer for Chevrolet Motor Co., mentioned a machine recently developed by Cleveland Graphite Bronze Co., which produces a bimetal bearing material — steel and babbitt perfectly bonded. The preparation of the steel, the fluxing, preheating, bonding, and the pouring of the bearing metal are all done automatically and in a continuous process. This machine would supplant the centrifugal spinning of bearings now done in a number of plants.

ANOTHER circular ("monograph" would be a better word) on the common metals has been issued by the Bureau of Standards. The latest one is on zinc and its alloys, sells for 70c, and is a 200-page compilation and critical summary of published information on physical properties, together with some new work on the pure metal by Louis Jordan of the Bureau staff. Much of the first 100 pages is devoted to the metallography, chemistry, and physical properties of rolled zinc sheet, thus reflecting the extensive research work of New Jersey Zinc Co. to discover the proper field of application for high grade metal. Consideration of zinc coatings of various kinds occupies another 30 pages. The remainder of the book is devoted to about two dozen binary alloy systems and several ternary and more complex alloys. Equilibrium diagrams of the binary alloys are included, although it must be remembered that the brasses (Cu-Zn) are the only ones which are articles of commerce at present, and this circular pays attention only to the zinc-rich end of the diagram which is of little importance. One other important system is the Zn-Fe alloys which are formed, willy-nilly, in the galvanizing process. Of the ternary alloys the Zn-Al-Cu-Mg die casting alloys are by far the most important, although a long list of complex bearing metals (Zn-Sn-Cu or Zn-Sn-Sb with or without lead and aluminum) is given for what they are worth. Each subdivision of this excellent cir-

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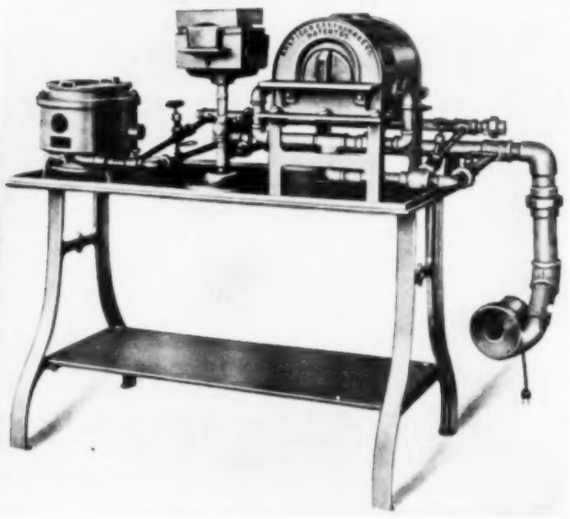

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cular ends with a selected bibliography from 1910 to 1930, which will bring more complete information to the investigator.

HARDENING of aluminum alloys of the duralumin type was first explained in 1919 by P. D. Merica, R. G. Waltenberg, and H. Scott of the Bureau of Standards on the supposition that submicroscopic particles of $CuAl_2$ formed from a supersaturated solid solution, and these hardened the alloy by slip intereference. This **PRECIPITATION HARDENING** has since been studied intently, and appears to be a common phenomenon rather than one unique to aluminum. Much evidence has been accumulated, especially by Europeans, on the mechanism of the process, from which it appears that the operation is not always so simple, and that recognizable compounds do not appear until duralumin is "over-aged" or heated to 400° F. or more. This matter was discussed by Dr. Merica in the Institute of Metals Division lecture, New York, Feb. 17. In hardenable alloys containing pure aluminum and pure copper in mutual solid solution, the lattice constant, as determined by X-rays, does not change at room temperature while the tensile strength is increasing, nor does the microscope or the spectrogram show any signs of $CuAl_2$ in the fully aged specimens. The dilatometer also shows that these pure alloys do not expand during age hardening at room temperature as they should, theoretically, if $CuAl_2$ were formed, nor does the electrical resistivity indicate any breakdown of a single phase alloy. Dr. Merica observed that there are several steps or stages between atoms and molecules, and one of these may be an accumulation of copper atoms at numerous favored locations, which, without forming definite groupings in space, and consequently not forming a second phase, do distort the surrounding space lattice considerably and cause large changes in hardness. In this he accepts the suggestion of German investigators. Why this copper should diffuse out of uniform solid solution to form "knots" is not yet clear.

Reviews of Recent Patents

By NELSON LITTELL
Patent Attorney
22 E. 40th Street
New York City
Member of A.S.S.T.

Arc Welding, *by Arthur W. Priebe, Milwaukee, assignor to A. O. Smith Corp. 1,839,437; also No. 1,840,251, by Arthur W. Priebe and Julius B. Tiedemann, Milwaukee, assigned to the same company; Jan. 5.*

Both patents concern the electric arc welding method and apparatus. It is pointed out that the position of the ground terminal which connects the welding circuit with the work piece has a definite bearing on the stability and desired control of the arc, and a proper positioning of the ground terminal will give a more rapid penetration of the arc and a better fusion of the metal. The two patents are very closely analogous, one covering the method and the other the apparatus. The apparatus of the first patent will be more particularly described. A pipe formed from a blank has a longitudinal seam to be welded. A weld rod is provided from which an electric arc extends to the pipe, and the pipe is grounded by means of ground terminals of which there are two, each contacting with the pipe at spaced points transversely of the pipe. The supporting arm is mounted on a suitable shoe or sleeve which may be moved longitudinally along the pipe through a suitable mechanism controlled by a crank. The ground connection may therefore be moved for various working conditions, as for example, when striking the arc and during the welding, and when welding different lengths of pipe, and also when welding several layers. Material operating advantages can thus be obtained.

Annealing, *by Lester L. Lewis, New Castle, Pa., assignor of two-thirds to Blair Strip Steel Co. 1,835,411; Dec. 8.*

This invention relates to annealing pots and has more particularly to do with the seal for the housing to prevent the introduction of air and for more uniform distribution of the protecting gas. The pot is mounted on a tray having track-receiving grooves and a flange. A sealing space is provided for sealing material. A gas port extends entirely around the flange. A second port is formed in the wall of the pot. After the required baking the tray and pot are removed from the furnace and the furnace and the connections for the pipes are fixed to supply gas under pressure until the cooling operation has been completed. Apparently the gas delivered creates an upward pressure and burns, thus counter-balancing atmospheric pressure and preventing any air from finding its way into the pot under the edges. The gas does not apparently affect the work, as steel with highly polished surfaces can be produced.

Welding Apparatus, *by Herbert O. Rich, Revere, Mass. 1,839,500; Jan. 5.*

A welding jaw or electrode holder in which arcing is eliminated and heating effects of the current are reduced is herein described. The shank is integral with the lower half of the jaw and the upper or movable jaw is pivotally secured. A lever, preferably insulated, operates on a suitable screw and bolt to force the upper body downward so that the tip contacts with the weld rod. Suitable grooves in the lower part of the jaw permit the weld rod to be held in any one of a number of angular positions and as the securing means is entirely back of the front point the construction may be termed an "inboard" mounting to allow the operation of the jaws in restricted positions.

(Continued on page 87)

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Alloy, *by Howard Scott, Wilkinsburg, Pa., assignor to Westinghouse Electric & Manufacturing Co. 1,843,903; Feb. 2.*

This iron-nickel alloy has a high coefficient of expansion and is therefore particularly useful as an element of a composite bi-metallic article and can be used as a substitute for brass or Monel metal. It contains between 5% and 30% of nickel, from 12% to 2% of manganese in accordance with the amount of nickel present and not to exceed 0.3% of carbon; the amount of nickel plus two and one-half times the manganese being not less than 30% of the alloy, the remainder being iron and minor impurities.

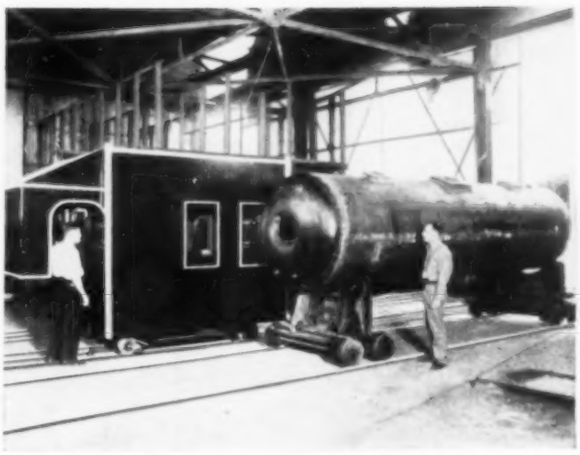
Case Hardening, *by John J. Egan, Brooklyn, New York, assignor to Electro Metallurgical Co. 1,837,256. Also No. 1,837,272 by Augustus B. Kinzel, Beechhurst, N. Y., assignor to the same company; Dec. 22.*

These patents describe a process of case hardening by heating the metal in nitrogen-containing agents such as ammonia. The object is to provide means for accelerating and intensifying the action of the nitriding gases to reduce the time for producing a given hardness or thickness. In one device an ionizing influence is provided whereby an arc, spark, corona, or other form of electrical discharge is produced in the nitriding gas, which discharge is preferably in close proximity to the surface of the specimen. Such effect has been found to reduce the normal time for a particular process from twenty hours to a period of four hours. The other patent describes an irradiating treatment by which the specimen is treated with ultra-violet energy, preferably produced external to the treating chamber and introduced through a window of quartz glass.

Inhibitor, *by James C. Vignos, Nitro, W. Va., assignor to the Rubber Service Laboratories Co. 1,843,653; Feb. 2.*

This inhibitor for pickling baths avoids the high vaporization of the heretofore used aldehydes of the aliphatic acids. The metal treating compound is preferably thialdine, which is the hydrogen sulphide derivative of aldehyde ammonia and is employed with sulphuric acid in the proportion of less than 0.1% of the acid solution.

(Continued on page 90)



General Electric X-Ray Installation for Boiler Inspection at Chattanooga Plant of Hedges-Walsh-Weidner Company.

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Quenching—A new 80-page book, "Houghton on Quenching," containing over 30 charts and photomicrographs, has just been published by E. F. Houghton and Co. MM-38.

Electrotinning—Roessler & Hasslacher Chemical Co., is offering a booklet describing electrotinning with the R & H sodium stannate-acetate plating bath, giving information on methods of preparation, operation and control. MM-29.

Nitriding Steel—Properties of a new chromium-vanadium nitriding steel developed by Union Carbide & Carbon Research Laboratories are listed in a new publication of Electro Metallurgical Sales Co. MM-16.

Chrome Brick Refractories—E. J. Lavino & Co. Folder discussing chrome brick made by a new process. Test data on spalling, sagging and hot load are given. Bulletin MM-40.

Welding Electrodes—Metal & Thermit Corp. has published a folder outlining the advantages of Murex mineral coated welding electrodes. Several types of electrodes are described. MM-64.

Fuel Valve Controller—Automatic Temperature Control Co. Leaflet describes a multi-position motor operated controller used for furnace temperature and atmosphere regulator, incorporating in one unit the desirable features of several older types. Bulletin JA-82.

Aluminum and Its Alloys—Aluminum Company of America has prepared the book "Alcoa Aluminum and Its Alloys" which presents data and tables on the physical and chemical properties of aluminum alloys. MM-54.

Neutral Atmosphere which makes possible the hardening of high speed steel without scale, decarburization or carburization, is explained by the bulletin, "The Sentry Diamond Block Method of Hardening High Speed Steel," issued by the Sentry Co. MM-84.

Optical Instruments—Bausch & Lomb Optical Co. has issued a new 128-page book, "Optical Instruments for Examining and Analyzing Metals. Information on establishing metallurgical laboratories; optical information for the metallographer; spectrographic analysis, etc. MM-35.

American Electric Furnace Co. have just issued a new catalogue insert No. 17 showing recent series of 6 and 8 inch electric pot furnaces for lead, salt, and cyanide work. MM-2.

Recorder Controller—Bristol Co. A new booklet describes Bristol's recently announced free vane air operated recorder controller. The instrument and its operating principles are graphically described. Bulletin JA-56.

Electric Heat Treating Furnaces—Ajax Electric Co., Inc. Photographic description of new electric furnaces for annealing wrought products, such as sheet, wire, tubing, rod, etc. Bulletin D-83.

Welded Construction Folder—Bethlehem Steel Co. Folder describing the use of rolled steel shapes and plates for the building of machinery parts by welding. The results are said to be sturdier construction, reduced weight, low cost, and elimination of patterns. Bulletin N-76.

Heat and Corrosion Resistant Alloys—General Alloys Co. A new bulletin is available on chrome-nickel and straight chrome heat and corrosion resisting alloys. Bulletin D-17.

High Frequency Induction Furnaces—Ajax Electrothermic Corp. New bulletin gives detailed information regarding Ajax-Northrup high frequency induction furnaces operated from static converters, for laboratory use or for small-scale production. Bulletin JA-41.

Conveyor Belt Handbook—Wickwire Spencer Steel Co. A new loose-leaf handbook, describing various types of metal conveyor belts for high and low temperatures. This includes the new heavy duty "Alpha" link belt, "Delta" plate belt and spiral type. Bulletin N-37.

High Test Welding Rod—The Linde Air Products Co. A 12-page booklet describing the qualities and advantages of high test welding rod. Extensively used for fabrication of pipe lines, pressure vessels or other welding operations where high strength and economy are required. Bulletin D-63.

Alloy Products—The Pressed Steel Co., in their new catalog, give interesting data relative to Rezistal Lite-Wate carburizing and annealing containers and other equipment. Bulletin D-67.

Thermit Welding—Metal & Thermit Corp. A 52-page booklet on the thermit welding process and its applications. Photographs and descriptions typical of its varied uses are given, showing how Thermit is fundamentally adapted when large sections are involved. Bulletin D-64.

Gears Made of Armor Plate—The International Nickel Co. Reprint of article by Robert E. Bultman originally published in May, 1931, issue of METAL PROGRESS. Booklet deals with the use of 5 per cent nickel and nickel-chrome steels for motor truck gears and pinions. Bulletin D-45.

Hy-Ten Alloy Steels—Wheelock, Lovejoy & Co., Inc. "Pertinent Points" folders covering physical properties, heat treatment and applications of all grades of Hy-Ten Special Steels. Bulletin D-22.

Industrial Application of the X-Ray—General Electric X-Ray Corp. Booklet gives many examples of the use of the X-Ray in the industrial field. Profusely illustrated with radiographs of castings, welds, assemblies, etc. Bulletin D-6.

Furnaces for the Steel Industry—The Electric Furnace Co. have issued a four-page folder illustrating and listing several electric and fuel fired furnaces of various types they have installed in steel plants. Bulletin D-30.

Modern Industrial Furnaces—Surface Combustion Corp. Booklet covering the research, development and engineering activities of the Surface Combustion Corp., and their application and the advantages obtained by S-C furnace users as a result of these factors. Bulletin N-51.

Rotary Hearth Furnace—W. S. Rockwell Co. has issued a new bulletin on its furnaces of this type, utilizing either electric or fuel heat. Construction advantages are explained and diagrams presented. Bulletin R0322.

Rail Steel Products—Republic Steel Corp. Booklet describes company's mill products, such as structural shapes and tubing, made from reclaimed rail steel. Weights and information on extras are included. Bulletin JA-8.

Ingot Molds—Gathmann Engineering Co. The subject of ingot molding is covered in a new book on this subject. Numerous illustrations of the effect of various methods of finishing and casting on the reliability of steel products are given. Bulletin D-13.

Machine Heat Treating—American Gas Furnace Co. A 16-page illustrated booklet giving information on the various types of conveyor heating machines available for heat treating on a production basis. Bulletin D-11.

Potentiometer Pyrometer—The Brown Instrument Co. 16-page booklet explaining and illustrating the principal features of the new Brown potentiometer pyrometer with special reference to accuracy of operation and ruggedness in service. Bulletin N-3.

Cold Finished Bar Bulletin—Joseph T. Ryerson & Sons, Inc. Bulletin describing the wide variety of shafting screw stock, and open-hearth case carburizing steels in use today. A range of products is given, a list of standard tolerances and S. A. E. specifications. Bulletin O-50.

Electric Steam Generators—General Electric Co. Booklet describing and illustrating G. E. electric steam generators for process work. A list of applications is included showing how these generators may be used in a wide variety of industries. Bulletin D-60.

Scale Prevention—Dearborn Chemical Co. Booklet describing latest scientific methods of treating water for prevention of scale, corrosion and foaming in steam boilers, dealing with related problems in connection with scale and corrosion in other power plant equipment. Bulletin D-36.

Heat and Corrosion Resistant Alloys—Michigan Steel Casting Co. A 16-page bulletin describing and illustrating various cast, rolled and fabricated alloy structures for use at high temperatures. Bulletin N-12.

Globar Elements and Accessories—Globar Corp. A new leaflet containing a list of standard industrial type Globar electric heating elements and a coordinated list of terminal mountings and accessories. Bulletin N-25.

Furnace Parts—Driver-Harris Co. has issued a bulletin featuring furnace parts made of their alloys. This bulletin gives data and advantages of Nichrome and Chromax heat resisting alloys in the form of furnace parts. Bulletin N-19.

Automatic Metallographic Polishing Machines—E. Leitz, Inc. Catalog illustrating and describing the Guthrie-Leitz automatic polishing machines of the one, two and four-spindle types. The new Leitz specimen clamps are also described. Bulletin N-47.

Fatigue Testing Machine—Thompson Grinder Co. Interesting data on fatigue testing and description of the rotating beam type of fatigue testing machine are given in Bulletin D-23.

Industrial Gas Heat—American Gas Association. A veritable textbook on the uses of gas heat in industry, profusely illustrated with photographs of installations, etc. Bulletin D-10.

Recuperators—Carborundum Co. The complete story of Carborundum Co. recuperators for industrial furnaces, describing the type and covering operating conditions. Bulletin F-57.

"Carbonol Process for Carburizing Steels" is the title of the new 12-page bulletin published by the Hevi-Duty Electric Co. The bulletin describes the results and advantages of the Carbonol process of carburizing. Bulletin N-44.

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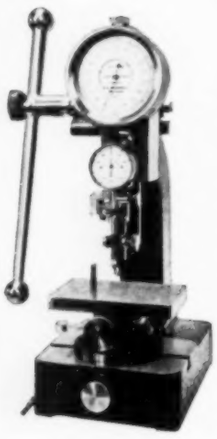

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Heat Treating Rails, *by Edward F. Kenney, Bethlehem, Pa., assignor to Bethlehem Steel Co. 1,837,189; Dec. 22.*

In the heat treatment of rails and similar massive bodies, this invention is intended to obviate the formation of permanent strains and to obtain the proper temperatures for the respective portions of the rail. The rail is allowed to cool from the mill heat until an edge of one of the flanges becomes magnetic, at which stage the greater mass of the rail is still above the critical range. The rail is immersed in a water bath for thirty seconds and is immediately immersed in a bath of molten lead at about 1000° F., during which period it is maintained at such temperature for a period of approximately forty-five minutes. It is then transferred to a closed furnace for a period of between 60 and 90 min. and is then allowed to cool in air. The rail is therefore substantially cooled rapidly through the critical range, and secondly further rapid reduction of temperature in the lead bath, and thirdly the drawing of the metal in the furnace, and fourthly the final cooling to atmospheric temperatures. It is to be understood that although the immersion in the lead bath immediately follows the removal from the water bath, such handling requires time changes preferably kept to a period of twenty seconds or less. The drawing of the metal produces a sorbitic or troostite-sorbitic micro-structure.

Core Paste, *by James F. McDowall, Akron, O., assignor to the B. F. Goodrich Co. 1,837,877; Dec. 22.*

Molds having cores made in sections for complicated castings are covered by this patent which particularly points out a novel paste composition comprising a solution of an adhesive binder in a volatile organic solvent and a considerable proportion of a flake pigment. The adhesive binder is preferably a tough, heat plastic, balata-like rubber isomer, such as that prepared by the action of rubber with sulphonic acids. They are soluble in the ordinary rubber solvents including gasoline and the natural isomers such as gutta-percha may be used. The flake pigment may be flake graphite, aluminum flake, or other flaky material which is suspended in the proportion of from one-half to two times the volume of the rubber isomer.

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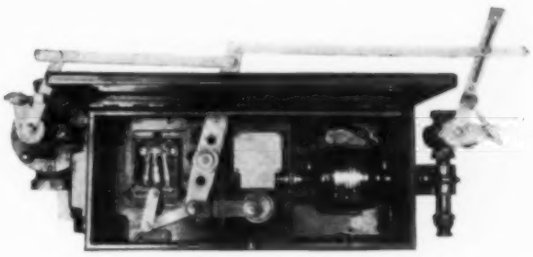

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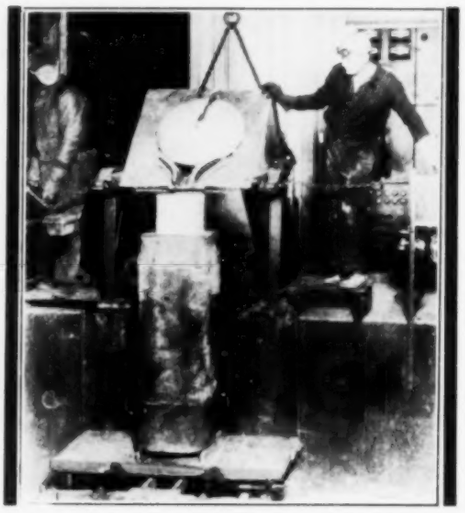

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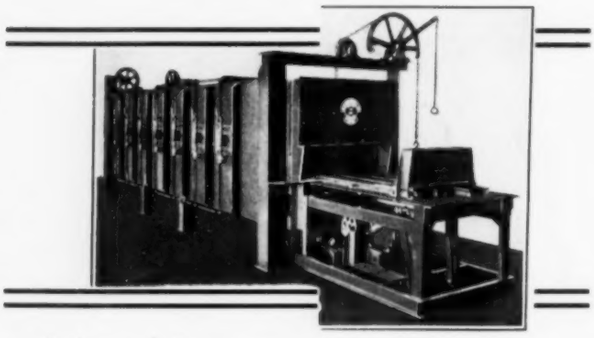

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(Continued from Page 72) in the eastern hemisphere, is situated here. The meeting began on October 17 and ended five days later.

Among the most important papers may be mentioned one describing experiments on reduction of vanadium contained in iron sands and on the slags produced in iron sand smelting; another on the formation of titanium nitride obtained by the reduction of titanium dioxide with solid carbon.

Japanese Discuss Many Aspects of Metal Science

Papers about steel included one on the relation between hardening effect and carbon content in nitriding steels; one on the effect of carbon on the properties of manganese steels; an investigation of acid-resisting steels; a contribution on the crystal structure of cementite; another on the structural constitution and transformation points in chromium steels; and the last on two kinds of martensite found in quenched steels.

Among the other recent occurrences of interest to Japanese metallurgists is the opening of a new low temperature laboratory at the Research Institute for Iron, Steel and Other Metals at Sendai. It occupies a two-story building covering a foundation area of 3200 sq.ft. Equipment includes a Claude air liquefying apparatus and a Heylandt hydrogen liquefying apparatus, the former having a capacity of 30 liters per hour and the latter 10 liters per hour. With the Claude apparatus, we can also obtain liquid nitrogen at the rate of 25 liters per hour; this is used, among other things, for a precooling medium for hydrogen liquefaction. Hydrogen gas is obtained by electrolytic cells of the Schuckert type, its purity being 99.9%. The building itself cost 39,300 yen, the apparatus and its installation 110,700 yen, so that the total expense amounted to 150,000 yen ($55,000 at the present rate of exchange). The acceptance tests showed that far more than 10 liters of hydrogen is liquefied per hour, and so the present apparatus is at present the largest in the world.

KOTARO HONDA